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..... tactile map symbols  
.....  
submitted by ..... Bonnie Sadler Takach  
.....  
in partial fulfillment of the requirements for the degree of Master of  
Visual Arts  
.....







Information design  
for the visually impaired:  
Tactile map symbols



# Information design for the visually impaired: **Tactile map symbols**

**MVA thesis project report**  
Bonnie Sadler Takach  
January 1989



## *Acknowledgements*

The author wishes to thank the following for their help and advice throughout this thesis project:

### Thesis supervisor

**Prof. Jorge Frascara**  
*Art & Design*

### Thesis advisors

**Prof. Peter Bartl**

*Art & Design*

**Prof. Bruce Bentz**

*Art & Design*

**Dr. Bridget Elliot**

*Art & Design*

**Dr. Eugene Lechelt**

*Psychology*

### Technical advisors

**Mr. Tom Kalkman**

*Industrial Design*

**Mr. Steven Dixon**

*Printmaking*

**Ms. Louise Asselstine**

*Visual Communication Design*

**Mr. David Roles**

*Visual Communication Design*

**Mr. Lee Broderick**

*Sculpture*

**Mr. Blair Brennan**

*FAB Gallery*

**Acrofoam & Plastics**

### General advisors

**Dr. Tom Nelson**

*Psychology*

**Ms. Marion Nicely, Director**  
*Disabled Student Services*

**Ms. Lydia Bardak**

*Orientation & Mobility*

*Specialist, CNIB*

**Staff, CNIB**

**Orientation & Mobility Support**  
**Group, CNIB**

**Mr. Tom McFall**

*Industrial Design*

**Dr. Tom Johnson**

*Psychology*

**Mr. Ron Torgerson**

*Computing Systems*

**Ms. Janet McDonald**

*Computing Systems*

**Mr. Chuck Humphrey**

*Computing Systems*

### General assistance

**Mr. B. O'Steele**

**Mr. Ron Whistance-Smith**

*University Map Collection*

**Ross McLaughlin**

*Geography*

**Staff, Art & Design**

**Ms. Melaine Osolinsky**

**Volunteer subjects**

**Staff, University Archives &**  
**Collections**

**Crown Paper**

**Ms. Virginia Penny**

**Ms. Susan Colberg**

**Ms. Corrie Heringa**



## *Abstract*

A system of 45 tactile surfaces consisting of 15 point, 15 line, and 15 texture symbols was developed for use in the design of maps for the visually impaired based on criteria found in studies on tactile perception. This set of symbols was tested for discriminability through the sense of touch in pair comparisons involving 38 subjects who were sighted, partially sighted or blind. Confusion matrices were tabulated with and without confidence factors to show the frequencies of confusion between symbols in the point, line and texture symbol groups. The relative performance of each symbol was graded to determine effective subsets of the three symbol groups. A map which incorporates some of these symbols in combination was designed to demonstrate how the results of this investigation might be applied. This study extends the field of information design to address the design of orientation aids for the visually impaired, specifically to consider the development of symbols to facilitate tactile perception. Recommendations for further study, testing and application have been outlined to provide starting points for further development in the design of information for the visually impaired.



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*This thesis project report describes the design, testing and application of a proposed system of tactile symbols for use in the design of maps and other information aids for the visually impaired.* 1.1

One of the most significant challenges to visual communication designers in association with specialists in other disciplines, is to develop materials that will extend the human ability to perceive and use critical information, that which is essential to an individual's health, safety and general well-being. Safety instruction manuals, food and drug labels, transportation schedules and travel maps are a few of the aids that people can consult to find critical information. Alternative modes of information retrieval are required for the visually impaired when restrictions in vision interfere with their ability to use conventional aids which cater to the fully sighted.

Information relating to orientation is critical for the visually impaired. Graphic orientation aids, or maps, containing information recognizable through vision and touch have the potential to enable individuals with different levels of visual impairment who possess motivation and some haptic capability to learn important spatial concepts and to plan independent travel routes. Researchers, orientation and mobility specialists and the visually impaired themselves support the use of these visual/tactile aids, yet, when available, they are largely underused. The design, production and training in use of these maps must be studied to determine how they can be improved.

In this thesis project, the first step of analyzing the design of visual/tactile maps was undertaken in relation to the presentation of tactile information. One factor possibly affecting the effectiveness of tactile maps is that they are often converted from maps for the sighted. In surveying tactile symbols which have been tested for discriminability and used in maps for the visually impaired, it appeared that in many cases, the symbols had been converted from conventional printed graphics and had not been designed specifically to enhance their perception through the sense of touch. This project addresses that problem in an attempt to develop maps for the visually



impaired that are not based on extrapolations of the experience of the 1.2  
fully sighted, but on empirical research studying tactile perception.



## 2

### Problem

### Improving

### visual/tactile maps

*Maps specifically designed for the visually impaired possess tremendous potential to enhance their learning of spatial concepts and to facilitate their planning of travel routes. For those individuals with haptic capability but restricted visual ability, effective tactile symbols can complement or replace printed counterparts. The design of such visual/tactile maps must extend beyond converting existing printed configurations to tactile form. Effective tactile symbols should be systematically developed specifically to facilitate the tactile perception of information.*

2.1

#### **Definition of terms**

The term "visually impaired" refers to the group of people with a variety of visual disabilities whose level of usable vision ranges from partial to non-existent. The term "blind" is used here to refer to individuals having no usable sight. The term "visual" pertains to the sense of sight, and "tactile" and "haptic", to the sense of touch. The term "orientation aid" denotes any device or method which enables individuals to travel confidently in any environment. The term "graphic" refers to marks or characters made on a surface, used here to mean a printed or raised surface. The term "map" describes a representation of spatial configurations indicated with point, line and area symbols.

#### **Orientation and the visually impaired**

Orientation is one of the greatest difficulties faced by visually impaired people. According to Foulke (1983), personal effectiveness is decreased by an inability to travel independently, safely and purposefully. To achieve independent travel, Foulke states that visually impaired travellers must have "spatial ability", the ability to "discover, by observation and inference" (p. 127) critical spatial arrangements. Spatial ability increases with mobility training, the use of effective orientation aids and subsequent travel experience.



### **Graphic orientation aids**

Wiedel (1983) suggested that in addition to promoting independent travel, orientation aids can promote increased awareness of spatial concepts. Similarly, Bentzen (1980) indicated that such aids can be used by the visually impaired:

to develop or enhance their understanding of basic spatial relationships, to facilitate their comprehension of specific travel environments, to refresh their memory of routes and areas, to further their skill in independent route planning, to enable them to travel independently in unfamiliar areas, and to add to their knowledge and enjoyment of physical space. (p. 291)

Bentzen divided orientation aids into three categories: models, graphic aids and verbal aids. She defined "graphic aids" as those which present information in tactile, visual or tactile *and* visual form.

Graphic aids such as maps may be used in appropriate cases to teach spatial concepts or may be used independently, after initial training, for route planning. Bentzen (1980) suggested that although graphic aids were not suitable for people with restricted tactile sensitivity, they were important to those visually impaired individuals who have difficulty in following verbal instructions and who require a better understanding of spatial concepts than can be gained through verbal descriptions. Graphic aids augment effective mobility training and may be used in combination with other orientation aids.

### **Visual/tactile maps**

Graphic orientation aids (or maps) which include visual and tactile information have been promoted by researchers (Sherman, 1965, cited in Bentzen, 1980; Angwin, 1968; Wiedel & Groves, 1969; Bentzen, 1980) as having the greatest communication potential for the largest



number of visually impaired individuals. When both printed and embossed, these visual/tactile maps can be read by the visually impaired and their helpers. These maps are inconspicuous because they look like conventional aids and are more economical than maps designed for people with specific vision problems or the totally blind because they can be used by individuals with various levels of visual impairment. Bentzen (1977) reported that persons with residual vision have been found to make use of both printed and raised information to the extent that they are able. For example, partially sighted individuals can use their residual vision to guide their tactile exploration (Heller, 1985).

The use of such maps is supported by the visually impaired who have specific orientation problems to solve. Any aspect of the environment of the visually impaired can be mapped (Armstrong, 1973), including intersections, floor plans and transportation systems. In a discussion with a group of visually impaired and blind individuals (Orientation and Mobility Support Group meeting, August, 1988), specific mapping needs were reported, namely the layout of specific intersections, bus transfer points, unfamiliar rooms (including furniture arrangement) and streets with the building entrances marked. Environmental cues such as raised international symbols for washrooms would be indispensable. For motivated individuals with some haptic ability, visual/tactile maps appear to present excellent alternatives to unusable conventional orientation aids. Why then are so few visual/tactile maps actually used?

#### **Design and production**

The physical and perceptual uses of maps for the visually impaired are affected by their design, production and training. Discrepancies have been noted relating to visual/tactile maps that may impede the development of coherent principles for their design and production and may ultimately affect their appeal and use. Some of these are outlined briefly here.

Although many psychologists and cartographers have



addressed the problem of designing maps for the visually impaired, no 2.4 studies on the subject have been found with input from industrial or graphic designers. Yet the relationship of content, media and function is central to the problem of developing effective maps for the visually impaired. For the most part, maps for many purposes are made by hand and there is no control over quality of design and production. Even apparently well designed maps are inadequate without effective training.

Enough environmental details must be included on the map to provide a wealth of information to the visually impaired user, but not enough to cause tactile clutter. The size of the map should be small enough to accommodate comfortable scanning with the hands, but large enough to include the symbol sizes required for tactile discrimination.

Production materials affect not only the discrimination of map symbols, but also the physical use of the map. Maps which are to be consulted en route must be portable, flexible and durable, yet the thin plastics that might match these criteria sometimes affect the legibility of the symbols. Symbols printed on plastic often become distorted or rub off. Maps produced from embossing paper are more economical to produce than their plastic counterparts, but do not wear as well.

The sighted and the visually impaired differ in the "physical, perceptual and cognitive means of dealing with [their environments]" (Hazen, 1983, p. 29), yet maps for the visually impaired are often simply converted from existing layouts that were originally intended for use by the fully sighted.

The design of **visual** information in visual/tactile maps must be perceptible by low vision users. Many potential low vision users do not read Braille. Although printed materials and conventional symbols may be used as an alternative, they must be redesigned to be visually useful to those with impaired sight. This may be as easy as using a bold typeface and as complicated as determining the optimum type size for legibility. Colour may be used for contrast, but it is difficult to predict how it will be perceived by those with widely varying visual



disabilities (Turk, 1983). Materials providing enough reflectance may also facilitate contrast, although glare must be avoided.

The design of **tactile** information in visual/tactile maps must be based on principles of tactile perception and discrimination. If partially sighted and blind persons are to be encouraged to make use of the sense of touch for perception, then information aids prepared for them must provide for optimum discriminability, recognition and ease of use. Foulke (1983) indicated that when information cannot be accessed through one sensory system, it may be received "either by sensory substitution or by resort to a perceptual alternative" (p. 129). However, this does not indicate merely a substitution of visual for tactile information.

#### **Discriminable tactile symbols**

Many tactile symbols that have been used as test materials for the design of maps for the visually impaired have suffered from being tactile versions of conventional printed graphics. This practice severely limits the number and variety of tactile symbols that could be potentially useful to the visually impaired. It also restricts the development and testing of optimal new forms which might, for example, be more compatible or easily associated with the landmarks that they would represent.

In one of the earliest studies of tactile symbol discrimination through active touch, Heath (1958, cited in Lederman & Kinch, 1979) tested tactile textures which had been converted from commercially available graphic patterns. He had selected these symbols based largely on visual criteria for discrimination. These were produced in raised fashion by the Virkotype method, in which fresh ink is sprinkled with resin, heated and allowed to harden. Subsequent studies which perpetuated this practice were undertaken by Nolan and Morris (1961, cited in Lederman & Kinch) and by Culbert and Stellwagen (1963), based on Heath's original visual selection. Although Nolan and Morris (1971) changed the production process to that of vacuum forming to increase the elevation of symbols, they still



used some of Heath's original textures in plastic for testing in addition to some other point and line symbols which were also converted directly from available printed graphics. Kidwell and Greer (1972) referred to the first point, line and texture symbols tested which were embossed into polyvinyl chloride as having been found on graphic arts transfer sheets. James and Gill (1975) based their selection of tactile symbols to be tested on criteria found in the previous tests. In her study of the relationship between production materials and symbol discriminability, Karentz (1977) tested symbols commonly found in visual graphics, but which were simple enough to be discriminated through touch. Lambert (1984) studied the importance of the association of tactile symbols and their referents, but developed symbols for testing based on visual symbology.

In a few cases, researchers have found a way to apply empirical data on tactile perception to the development of effective tactile symbols. The most innovative tactile symbol is a directional arrow developed by Schiff (described in Schiff, Kaufer and Mosak, 1966). This arrow, which feels smooth in one direction and rough in the other, fully illustrates the potential of applying well understood theories to practical situations (Jansson, 1983). Further attempts were made to find directional symbols for critical situations. Wiedel and Groves (1969b, cited in Bentzen, 1980), proposed a symbol to represent the presence of steps which featured a rectangle followed by three dots. James and Gill improved upon this symbol by gradually increasing the profile of the successive dots to show ascending or descending steps (1969, cited incorrectly in Bentzen, 1980).

All of these investigations and similar ones have contributed greatly to the growing body of empirical knowledge related to the tactile perception of map symbols. In the cases where tactile symbols have been studied in the context of maps, few have been tested in actual situations. Principles governing the design of discriminable tactile symbols must be derived from these and other related studies to apply to the development of effective tactile symbols.



## Designing a system of discriminable tactile symbols

*Parameters for the initial selection of features comprising potential tactile symbols were derived from the results of several studies of the tactile perception and discrimination of raised surfaces. Those features which affect the discriminability of tactile symbols were classified and combined systematically to generate numerous symbol configurations for possible inclusion in the proposed symbol set. Fifteen symbols with widely varying features were chosen from within each of the point, line and texture groups as a set of symbols which might easily be perceptible through the sense of touch. Forty-five symbols and some alternatives were photo-etched onto zinc plates and embossed onto paper for further study. These raised surfaces were informally inspected by touch to determine what refinements would be necessary to produce a system in which the features of each symbol would differ from those of every other in as many ways as possible. So that the discriminability of this proposed system might be evaluated by pair comparisons, test pairs were prepared for 120 possible pairings of 15 symbols in each of the point, line and texture groups.*

3.1

### Criteria for the design of tactile symbols

Criteria for the development of discriminable and recognizable tactile symbols may be gathered from the numerous studies done in the areas of tactile perception and tactile symbol discrimination.

In sight, information is perceived holistically, while in touch, information is perceived sequentially (Revesz, 1950). This increases the difficulty of tactile scanning of maps and recognition of map symbols. Strategies for use will differ with every person, as will their cognitive abilities. Every effort must be made in the design of these maps to enhance the discrimination and recognition of tactile symbols.

The conventional symbol groups used in maps for the sighted and the visually impaired are known as point, line and area. Point symbols normally represent landmarks, line symbols normally represent trails or boundaries and area symbols normally represent regions of space. In this project, area symbols are referred to as texture symbols, as this more aptly describes the raised patterns developed.



3.2 Researchers who have studied the tactile perception of maps and graphics have offered guidelines that may be applied to the coding of tactile symbols. Some of these are outlined here. Symbols which some researchers have called "areal" are referred to by the term "texture" in the following descriptions:

#### *Contrast*

Symbols should differ from each other in as many ways as possible, and at least 25% to 30% in size (Nolan & Morris, 1971). Visual contrast does not provide a good indication of tactile contrast (Schiff, 1966, cited in Nolan & Morris, 1971). **Point** symbols should differ from each other in terms of shape, size, elevation, and outline. **Line** symbols should differ from each other in terms of delineation, dimension, roughness and frequency. **Texture** symbols should differ from each other in terms of intensity, density, interval and in the size, shape and direction of components (Bentzen, 1980).

#### *Complexity*

Maps should be simple and not cluttered with too many symbols (Schiff, 1966, as cited in Nolan & Morris, 1971). The smallest discriminable symbols should be used to accomplish this (Bentzen, 1980). Overuse of texture symbols should be avoided as it causes "tactile noise" (Berla & Murr, 1975, cited in Bentzen, 1980).

#### *Compatibility*

Wherever possible, the configuration of the symbol used should be easily associated with the information that it represents (Schiff, 1966, cited in Nolan & Morris, 1971; Lambert, 1984). Double lines are easily associated with roads (Gill, 1973a, cited in Bentzen, 1980).



### *Shape*

Shape recognition is one of the most difficult tactile tasks, but it is made easier by the use of small-scale symbols (Bentzen, 1980).

### *Delineation*

The discrimination of small outline shapes is difficult, especially when they are smaller than 12 mm in diameter (Schiff, 1966, cited in Nolan & Morris, 1971).

### *Traceability*

Lines must be designed so that they are easily traced or followed. The use of double lines allows for better tracking than one, if the lines are separated by 3.1 to 6.3 mm (Amendola, 1973, cited in Bentzen, 1980).

### *Dimension*

Tactile symbols must be much larger than visual symbols to facilitate perception (Nolan & Morris, 1961, cited in Bentzen, 1980). Point symbols should be small enough to fit under the fingertips of the reader (Bentzen). The minimum discriminable line length is from 12.7 to 25.4 mm, depending on the pattern (Nolan & Morris, 1971). Texture symbols with outer dimensions of 5 cm x 5 cm are easily distinguished by blind students and smaller symbols with a 2.0 cm dimension are often discriminable (Morris & Nolan, 1963). Small scale elements in texture symbols are easier to distinguish than large scale ones.

### *Elevation*

Tactile edges can be easily discriminated and sharpness ("intensity") facilitates tactile perception (Schiff, 1966, cited in Nolan & Morris, 1971). Differences in the intensity of texture elements are more easily perceived than the



shape or orientation of elements (Levi & Schiff, 1966, cited in Bentzen, 1980). Gill (1973) found that a discriminable elevation for point symbols is 0.85 mm. Wiedel and Groves (1969) found that 0.51 mm is a discriminable elevation for Braille dots; 1.52 mm, for point symbols and 1.02 mm, for line and texture symbols.

#### *Proximity*

Textures should not interfere with point or line symbols when used together (Berla & Murr, 1975, cited in Bentzen, 1980).

#### *Intersection*

The intersection of lines is discriminable if the lines are notably different and if one line is broken at the point of intersection (Schiff & Levi, 1966, cited in Bentzen, 1980.)

#### *Spacing*

A minimum space of 2.3 to 3.8 mm between point symbols has been suggested by Schiff (1982). The spacing between dots in a line identifies lines, but the spacing between dashes in a line does not (James & Gill, 1975).

#### *Orientation*

For direction to be a discriminable feature, the scanning of texture symbols must occur in many directions (Schiff, 1966, cited in Nolan & Morris, 1971). Orientation should not be used as a discriminable feature in point or texture symbols (Pick, Klein & Pick, 1966, cited in Schiff, 1982).

#### *Indexing*

Adding (Braille) labels often increases problems of tactile clutter (Wiedel & Groves, 1969). Information may be presented on an underlay (Kidwell & Grier, 1973) or



overlay, such as the grid margins (Armstrong, 1973), or other 3.5  
reference devices. Map legends should occupy a standard  
location (Armstrong, 1973).

### **Developing a proposed symbol system**

#### *Taxonomy of symbol features*

A programme for generating point, line and texture symbol features was developed in consideration of the formal guidelines suggested above. A taxonomy chart was devised (Fig. 3.1) which classified the following basic features and configurations of abstract symbols: *symbol group, frequency of features, shape of features, dimensions of features, elevation of features, delineation of features, configuration of features, relationship between features, rhythm of features, density of features and orientation of features*. The "configuration" classifications were adapted from Ching's book on order in architecture (1979).

#### *Generation of symbols*

Numerous possible symbols were generated by combining various features of the taxonomy chart. Specific guidelines for dimension and spacing outlined above were considered in the choice of symbol configurations comprising a testable set.

#### *Selection and production of acceptable symbols*

Fifteen symbols in each of the point, line and texture groups were selected among dozens of generated symbols as those which comprised the set with the most contrast between symbols. (A taxonomic description of some of the selected symbols can be found in Fig. 3.2.) These, along with some alternatives, were rendered graphically for photo-reproduction to be used in the photo-etching process (Appendix A.1). Symbols featured thin lines to accommodate the change of line thickness that would occur in the production process. This photo-graphic master was used to photo-etch the symbols into two 18 x 24 inch zinc plates with nitric acid, one to a minimum depth of approximately 0.5 mm and one to a maximum depth of approximately 1.0 mm. These plates were used to test symbol impression in both the



vacuum forming and mechanical embossing processes. Neither process gave an optimal result in terms of impression, so an initial symbol set was hand-embossed onto coated Iconofix paper by pressing styluses of different widths into the etched zinc plates. (Further testing would be required to determine the best mechanical process for symbol production.) The hand-embossed symbols were then inspected informally through the sense of touch to determine a potentially effective set for testing. Refinements were made based on further informal tactile observations. A final set of hand-embossed symbols (Fig 3.3) was prepared. From these 240 point symbols, 240 line symbols, and 240 texture symbols, testing materials for pair comparisons were prepared according to the method described in Section 4.



Fig. 3.1  
*Taxonomy chart of basic features  
 and configurations of abstract  
 tactile symbols*  
*\* sequence is repeated as  
 necessary for symbols with  
 multiple features*

<b>A Symbol group</b>	1 point...B 2 line...B 3 texture...B	
<b>B Frequency of feature(s)</b>	4 single...C multiple>>>>>>>>>>	5 homogenous...C 6 heterogenous...C <sup>n*</sup>
<b>C Shape of feature(s)</b>	7 curvilinear...D 8 angular...D 9 composite...D	
<b>D Dimensions of feature(s)</b>	10 large...E 11 small...E 12 composite...E	
<b>E Elevation of feature(s)</b>	13 high...F 14 low...F 15 composite...F	
<b>F Delineation of feature(s)</b>	16 solid...G outline>>>>>>>>>>	17 continuous...G 18 interrupted...G
<b>G Configuration of feature(s)</b>	19 singular...K 20 centralized...H 21 linear...H 22 radial...H 23 spiral...H 24 grid...H 25 composite...H	
<b>H Relationship between features</b>	26 unconnected...I connected>>>>>>>>>>	27 intersecting...I 28 not intersecting...I
<b>I Rhythm of features</b>	29 random...J ordered>>>>>>>>>>	30 symmetrical...J 31 asymmetrical...J
<b>J Density of features</b>	32 high...K 33 low...K	
<b>K Orientation of feature(s)</b>	34 neutral...A 35 multidirectional...A unidirectional>>>>>>>>	36 vertical...A 37 horizontal...A 38 diagonal...A





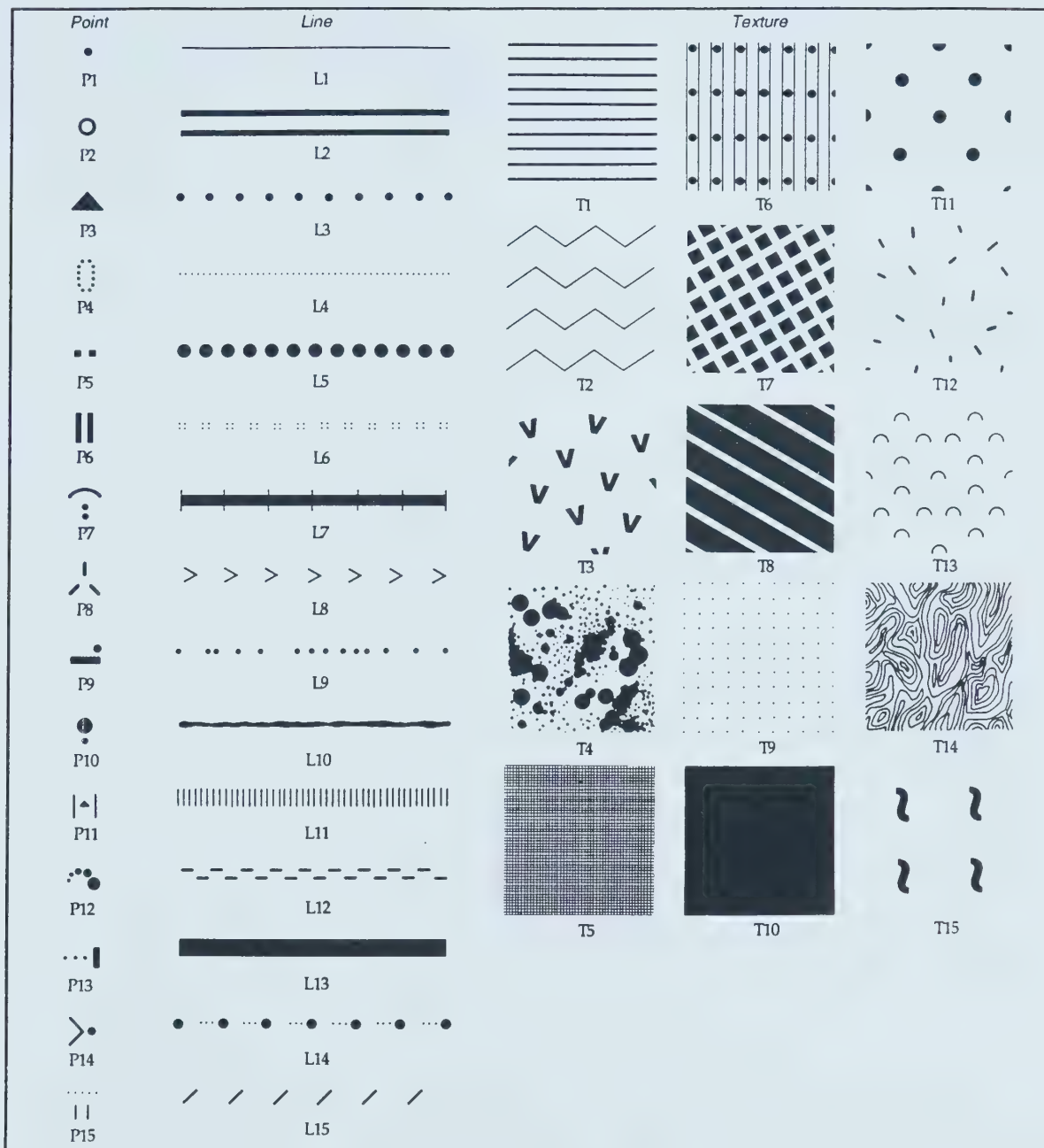
**Fig. 3.2**

**Example of taxonomic description**

**used to generate symbols**

**(shown at actual size)**





**Fig. 3.3**  
**Proposed symbols to be tested**  
 (shown at 50% actual size)



## Evaluation

### Testing the discriminability of the proposed symbols

*The relative discriminability of the proposed tactile symbols was evaluated according to the quantitative and qualitative methods described below.*

4.1

#### Purpose

The objective of the testing was to evaluate the relative discriminability of a proposed tactile symbol set of 15 point, 15 line and 15 texture symbols in order to determine which subsets of each group might be employed in the design of maps for the visually impaired.

#### Method

The relative performance of symbols was tested in a series of pair comparisons by sighted and visually impaired subjects, who examined the symbol pairs through the sense of touch with their hands under a vision barrier. Three random orders of the 120 possible pairs were balanced over twenty-one comparisons undertaken in each of the three symbol groups. Subjects were asked to judge if each symbol in each pair was the same as or different from the other. For an allied measurement, they were also asked whether they were confident in their answer. No time limit was imposed and subjects were encouraged to take breaks as needed.

#### Subjects

Thirty-eight volunteer sighted, partially sighted and blind subjects participated in the testing. They were between 18 and 64 years old and varied widely in education and vocation. Twenty-one of the 35 sighted subjects were female, 14 were male. The partially sighted subject was male. Of the 2 blind subjects, one was female, one was male. None of the sighted subjects had any training in reading Braille. The partially sighted subject used optic aids daily to extend his remaining vision and did not use Braille materials, although he was trained to read them. The two blind subjects maintained their skill in reading Braille. A large number of tactually inexperienced sighted subjects



were involved due to the small number of available, visually impaired 4.2  
persons. Horsfall and Vanston (1981) support the use of sighted subjects  
in tactile experiments on the basis that the tactile abilities of blind  
subjects would not vary greatly from those of sighted subjects.

### **Materials**

Fifteen surfaces in each of the point, line and texture groups were developed according to the programme described in Section 3. Test materials were prepared by hand-embossing 16 copies of each of the proposed 45 symbols onto coated paper, using photo-etched zinc plates as masters (*Appendix A.1*). The resulting 120 symbol pairs in the point, line and texture groups were numbered for ease of identification and arrangement according to their position on a master matrix of pair comparisons (*Appendix A.2*). For each of the symbol groups, test pair tiles were prepared to accommodate the comparison between each symbol with itself and all other symbols in its group (*Fig. 4.1*). Each pair of embossed symbols was glued to lightweight tiles made of Fomecor, a presentation material consisting of pressed foam, covered on both sides with coated paper. The tiles were stored in an upright position in trays for easy access.

#### *Point symbol pair tiles*

Each point symbol was hand-embossed onto the center of a 2.5 x 2.5 cm square of Iconofix coated paper. Each of the 120 required symbol pairs was glued to one face of a 7.5 x 2.5 x 0.5 cm Fomecor tile, separated by an area of 2.5 x 2.5 cm.

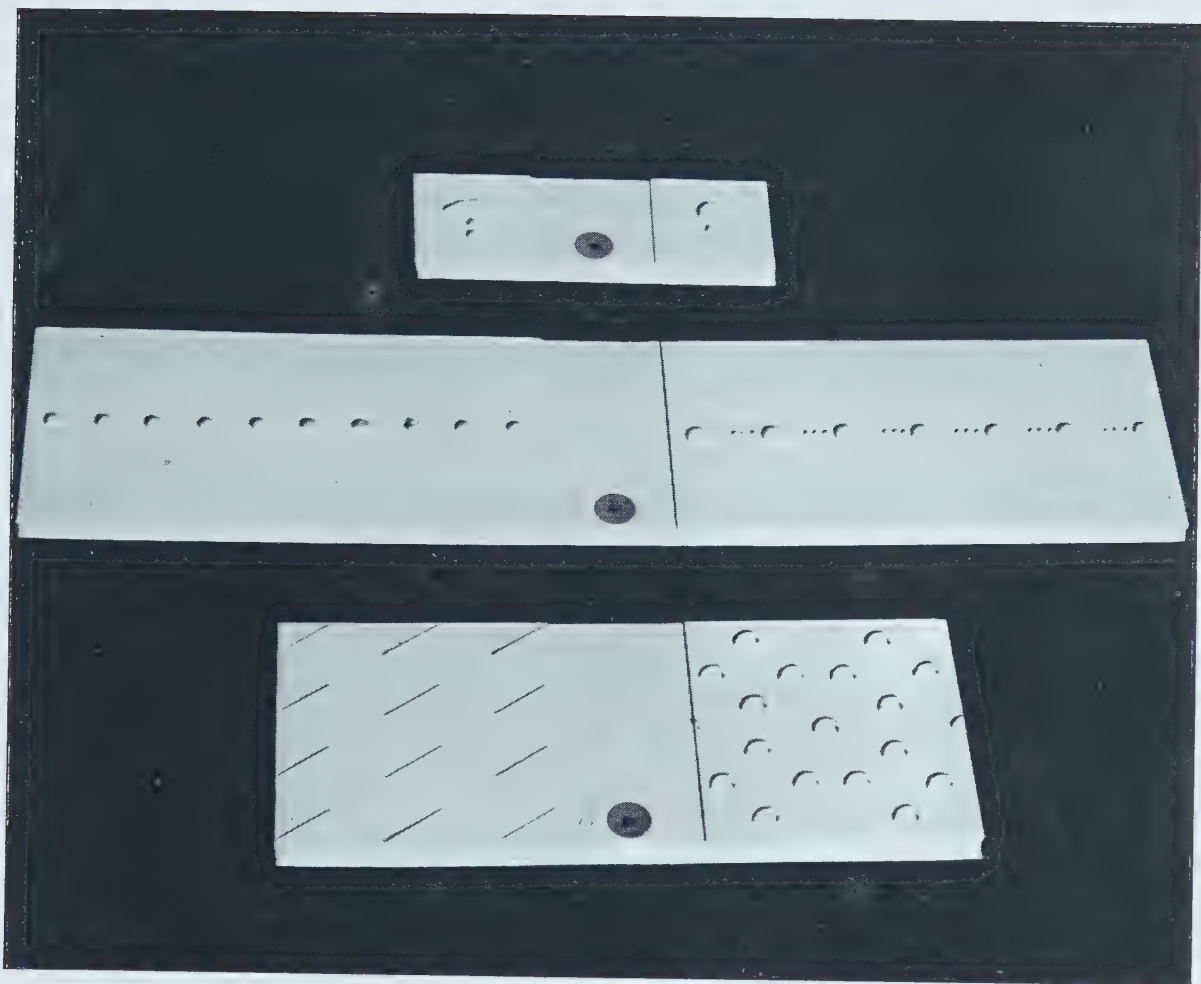
#### *Line symbol pair tiles*

Each line symbol was hand-embossed onto the horizontal centre of a 10.0 x 5.0 cm rectangle of Iconofix coated paper. Each of the 120 required line pairs was glued to one face of a 22.5 x 5.0 x 0.5 cm Fomecor tile, separated by an area of 2.5 x 5.0 cm.

#### *Texture symbol pair tiles*

Each texture symbol was hand-embossed onto the entire surface of a 5.0 x 5.0 cm square of Iconofix coated paper. Each of the 120 required texture pairs was glued to one face of a 12.5 x 5.0 x 0.5 cm





*Fig. 4.1*  
*Photograph showing examples*  
*of symbol pair tiles produced for*  
*testing*



Fomecor tile, separated by an area of 2.5 x 5.0 cm.

#### *Vision barrier*

A vision barrier was designed to ensure that the symbol pairs would be inspected through touch alone by the sighted and partially sighted subjects (Fig. 4.2). It was not used with the two completely blind subjects, who depended wholly on the sense of touch for discrimination. Four notched Fomecor panels were fitted together to form the structure, which resembled a table top lectern and sloped down towards the seated subject. The base of the barrier supported the structure and featured a cut-out guide which held the pair tiles in place while subjects examined the embossed surfaces actively with their fingertips (Fig. 4.3). Subjects were able to place their hands under the low front opening, which was wide enough to accommodate free hand movement, but low and long enough to obstruct their view of the pair tiles and of their hands. A high and wide opening at the back allowed the experimenter access to the tile guide, but concealed the placement of the pair tiles from the subject.

#### *Response sheets*

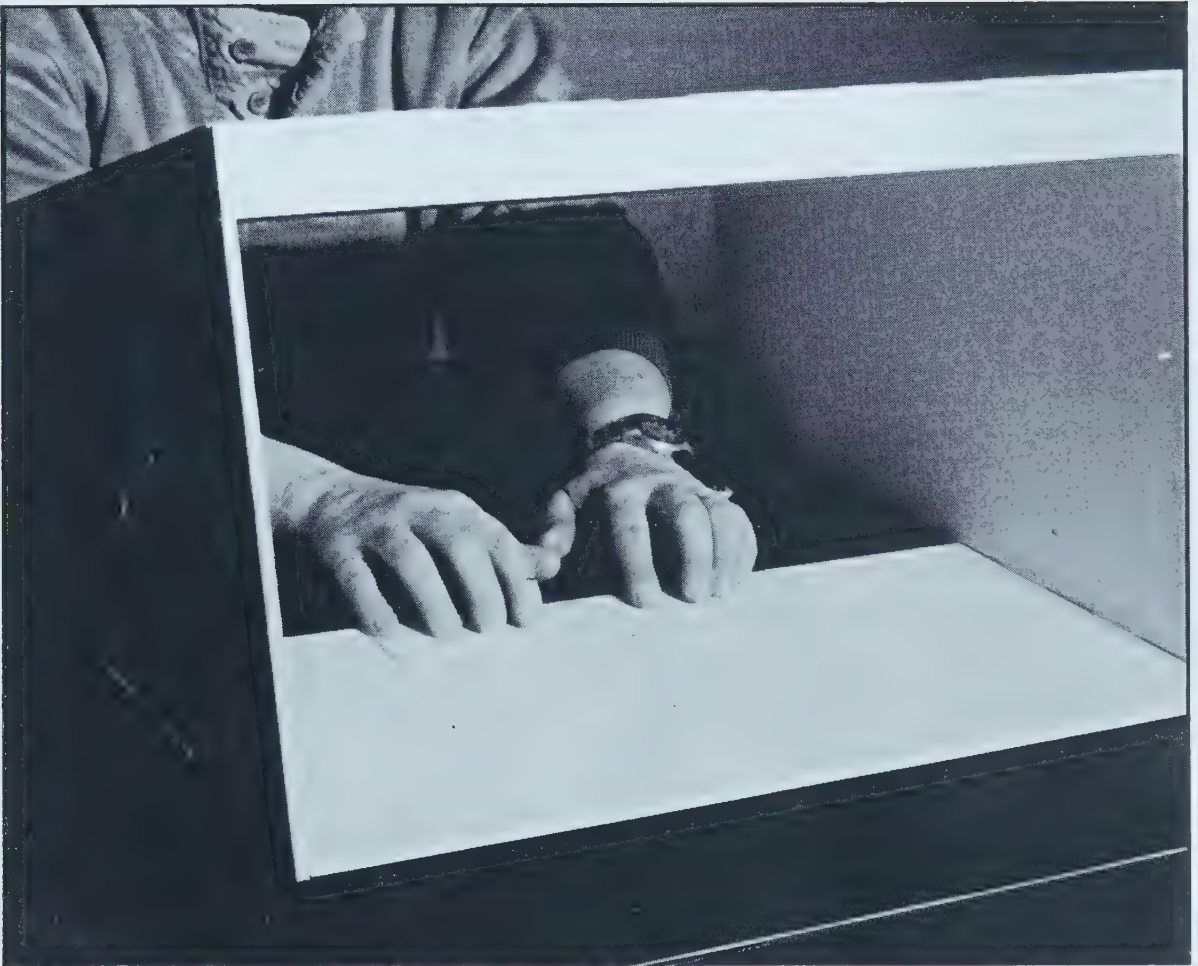
Nine forms were designed to accommodate answers to the questions of comparison and confidence for all symbol pairs tested, in three random orders of three symbol groups (Appendix A.3 to A.11). The questions were arranged in rows of six to provide an easily searched array for the experimenter to monitor the pair orders and mark responses. These forms were easily scanned for analysis after the testing.

### **Procedure**

#### *Test situation*

The testing was done in rooms that offered as little distraction as possible. Subjects were asked to sit facing the experimenter and in front of the vision barrier, which rested on a table (Fig. 4.4). They were encouraged to assume a comfortable position. After the first test by the first subject, an office chair was replaced by a more comfortable drafting chair.





*Fig. 4.2*  
*Photograph showing the vision*  
*barrier produced for testing*





**Fig. 4.3**  
*Photograph showing tile guides*





*Fig. 4.4*  
*Photograph showing testing*  
*situation*



### *Test description*

A prepared statement was read to each subject prior to the testing which briefly described the test as follows:

Thank you for participating in this test.

My name is ....

I will begin by reading a description of the test.

You are helping to test a proposed set of raised symbols to be used in the design of raised or tactile maps for the visually impaired.

**It is important for you to realize that it is the performance of the symbols that is being tested, and not your performance.**

The purpose of the test is to determine which symbols are most easily distinguished through the sense of touch.

The symbols are made up of **one or more elements** which may vary from symbol to symbol in terms of **size, shape, number, spacing and height**. They rest on backgrounds of the same size.

Participants are asked to feel and compare pairs of raised point symbols, line symbols or texture symbols. In this case, you will be examining: (Point symbols, which may be used on maps to locate landmarks. They are made up of one or more elements.)

(Line symbols, which may be used on maps to show paths or boundaries. They are straight lines made up of one or more elements.)



(**Texture** symbols, which may be used on maps to show specific areas. They are patterns made up of one or more elements.)

You will examine the symbol pairs, under this vision barrier, using fingers of **one** or **both** hands.

At this point, subjects were invited to or physically guided to place their hands under the vision barrier on the first pair tile to be compared. The vision barrier was moved if necessary to facilitate a comfortable sitting position when arms were extended for pair examination under the barrier. When subjects were comfortably positioned and familiar with where pair tiles would be placed, the description of the test continued as follows:

**Be aware that heavy pressure may dull the sense of touch.** It may be useful to explore the samples lightly, moving your fingers in a circular motion, up and down, and from side to side, in the same direction if you like.

**In each case you will be asked 2 questions;**

**The first question is**

"Do the samples feel the **same** or **different**?"

**The second question is**

"Are you confident in your answer, **yes** or **no**?"

The second question will help to determine whether samples are easily distinguished or not easily distinguished.

**There is no time limit, and you are welcome to take a break at any time.**

Do you have any questions?



At this point, testing began with the examination of the first symbol pair already in place under the vision barrier.

#### *Testing*

The sequence of the symbol pair tiles was determined according to the three random orders employed. Seven tests were done with the first random order, seven tests with the second random order and seven tests with the third random order for the point symbol pair comparisons; the same was done for the line and the texture symbol pair comparisons.

In each of the 63 tests, 120 possible pairs were compared, one after the other, according to the relevant random pair order. Each pair tile was taken from the front of the point, line or texture tile tray and placed in the tile guide on the base of the vision barrier. Subjects were permitted to examine the pair tiles out of the guide as long as the tiles remained under the vision barrier. As mentioned, the two totally blind subjects examined the pair tiles without the vision barrier or tile guide.

In each pair comparison, the subjects were asked whether the symbols felt the same or different and if they were confident in their response. After the first few questions, most subjects responded without needing the questions: "same-yes", "same-no", "different-yes", or "different-no". It was not insisted that subjects wait for the questions because the questions annoyed some subjects by delaying their responses. The two-part response for each pair comparison was circled next to the pair number on the response sheet. As soon as a response was given for each pair, the pair tile was taken out of the guide and placed at the back of the tile tray to keep a consistent arrangement for the next test with the same random order.

The experimenter was required to check every pair number on the tiles against the order on the response sheet to ensure that the responses were noted correctly for each symbol pair. No time limit was imposed and breaks were encouraged, but rarely taken. The time required for comparing 120 pairs in any symbol group varied from 15 minutes to 120 minutes. The average test time, without breaks, was



approximately 35 minutes.

At the end of each test, subjects were asked if they had any comments to make and if they had not already done three tests, whether they were interested in participating in another symbol test. Sighted subjects were not permitted to see the pairs unless they were not intending to participate in any more tests.

#### **Discussion of test results**

This testing was done primarily to determine the discriminability of symbols within the point, line and texture groups. Two types of data were collected during the pair comparisons: quantitative scores that were based on frequencies of confusion and qualitative notations that were based on general observations.

##### *Performance ranking*

Based on test results collected (*Fig. 4.5, 4.6 and 4.7*), two confusion matrices were prepared for each of the point, line and texture groups. One type showed only the frequencies of confusion (*Fig. 4.8, 4.9 and 4.10*) and the other showed frequencies of confusion in alliance with confidence factors (*Fig. 4.11, 4.12 and 4.13*). These were used in two different methods to determine scores for ranking the relative performance of individual symbols.

In the first ranking method, the relative performance of individual symbols was determined by calculating the total number of confusions for each symbol in all of its occurrences. (Each symbol was presented 15 times in 21 tests for a total number of 315 occurrences.) Symbols were ranked according to the number of times that they were confused with themselves or other symbols in all of their occurrences (*Fig. 4.14, 4.15 and 4.16*). This method is similar to the "rank order distribution" obtained by Culbert and Stellwagen (1963, p. 548) in their study of texture symbols. A similar performance ranking was discussed by Karentz (1977) in her study of the discriminability of tactile symbols in different materials.



In the second ranking method, an allied confidence measure was recorded and considered in addition to simple frequency counts. A confusion score was determined by attaching an arbitrary grade to confusions which ranged, in descending order, from most significant to least significant. A "confusion with confidence" response was assigned a grade of 3. A "confusion without confidence" response was assigned a grade of 2. A "non-confusion without confidence" response was assigned a grade of 1. A "non-confusion with confidence" response was assigned a grade of 0. This ranking method is considered to be a more accurate measure of individual symbol performance than the first ranking method, although the results were similar for both.

Regardless of performance ranking, no symbols were discarded, since only a small subset of any symbol group would be employed in maps for the visually impaired. In this way, no potentially effective combinations were overlooked. Symbols which did not perform well in combination with the other 14 in the group can still be effective in certain smaller subsets.

Further arbitrary measures may be applied to determine a quantitative threshold of relative discriminability of the proposed symbols. Fifteen point symbols, 10 of the 15 line symbols and 14 of the 15 texture symbols met the criteria of being discriminable in more than 95% of the 315 total occurrences (*Fig. 4.17*). If we were to apply the strict criteria of Nolan and Morris (1971) - that the confusion of a symbol acceptable by the above measure, with itself or any other symbol, must be 10 % or less - then the number of acceptable symbols would be drastically reduced due to the high number of confusions that occurred when symbols were compared to themselves (*Fig. 4.18*).

This high self-confusion phenomenon might relate to differences in function between the fingers of the left and right hands and to problems in manufacturing identical copies. Nolan and Morris (1971) reported this phenomenon in tests with visually impaired grade-school children and suggested that it might be due to the subjects' concentrating on finding differences in comparison. They proposed that subjects would look for likeness instead of difference in a map reading



situation. Jansson reported in 1983 that this frequently seen self-confusion phenomenon had still not been fully investigated or understood.

4.9

Given the uncertainties reported concerning the self-confusion phenomenon reported in tests similar to this one, the Nolan and Morris measure would not be applied to the selection of symbols for use in maps. However, it would be considered in selecting symbols to represent hazards or critical landmarks. Additional criteria for the selection of symbols would be based on their compatibility with the environmental features that they would represent.



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Dy1 Dn1 Sn1														
2		Dy3 Dn0 Sn2			Sy0 Sn0 Dn1		Sy0 Sn0 Dn1				Sy0 Sn0 Dn1		Sy0 Sn0 Dn1		Sy0 Sn0 Dn1
3			Dy7 Dn0 Sn0		Sy1 Sn0 Dn1	Sy2 Sn1 Dn1			Sy0 Sn0 Dn1			Sy0 Sn0 Dn1		Sn1Sy0 Sn0	
4				Dy2 Dn1 Sn0	Sy1 Sn0 Dn0	Sy3 Sn0 Dn0		Sy1 Sn0 Dn0					Sy0 Sn0 Dn1	Sy0 Sn0 Dn1	Sy2 Sn0 Dn0
5					Dy2 Dn1 Sn2					Sy1 Sn0 Dn1		Sy0 Sn1 Dn1		Sy2 Sn0 Dn0	Sy2 Sn1 Dn0
6						Dy5 Dn0 Sn0		Sy0 Sn0 Dn1		Sy1 Sn1 Dn1					Sy2 Sn0 Dn0
7							Dy4 Dn0 Sn0				Sy0 Sn0 Dn2	Sy1 Dn0 Dn0			Sy1 Sn0 Dn0
8								Dy3 Dn0 Sn0	Sy1 Sn0 Dn0		Sy0 Sn1 Dn2		Sy1 Sn0 Dn0	Sy3 Sn1 Dn1	Sy1 Sn0 Dn0
9									Dy3 Dn0 Sn1	Sy0 Sn0 Dn1			Sy0 Sn0 Dn2	Sy1 Sn0 Dn1	
10										Dy1 Dn0 Sn0	Sy1 Sn1 Dn0				
11											Dy1 Dn0 Sn4		Sy1 Sn0 Dn1	Sy1 Sn0 Dn0	Sy2 Sn1 Dn2
12												Dy5 Dn0 Sn4	Sy0 Sn1 Dn1	Sy0 Sn0 Dn1	Sy1 Sn0 Dn0
13													Dy3 Dn1 Sn1		
14														Dy5 Dn0 Sn2	Sy0 Sn1 Dn1
15															Dy2 Dn0 Sn3

Fig. 4.5

**Point symbol pairs**

Matrix showing the distribution of discrimination confusions in 21 tests.

$$\begin{array}{|c|} \hline \text{Wy1 Wn1} \\ \hline \text{Rn1} \\ \hline \end{array} = \begin{array}{|c|} \hline \text{Dy1 Dn1} \\ \hline \text{Sn1} \\ \hline \end{array} \text{ OR } \begin{array}{|c|} \hline \text{Sy1 Sn1} \\ \hline \text{Dn1} \\ \hline \end{array} \begin{array}{|c|c|} \hline 3x & 2x \\ \hline 1x & \\ \hline \end{array}$$

**Wy** = confident confusion

**Wn** = non-confident confusion

**Rn** = non-confident non-confusion

3 x **Wy**

2 x **Wn**

1 x **Rn**

The number of confusions without including a confidence measure was calculated by adding **Wy** and **Wn**. The results were entered into the confusion matrix in Fig. 4.8.

The number of confusions including a confidence measure was calculated by multiplying the different classes of discrimination confusions by an arbitrary grade. The sum of these grades was entered into the confusion matrix in Fig. 4.11.



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Dy2 Dn1 Sn0	Sy2 Sn0 Dn0					Sy1 Sn1 Dn0								
2		Dy4 Dn0 Sn1	Sy0 Sn0 Dn1				Sy0 Sn1 Dn0						Sy3 Sn0 Dn1		
3			Dy2 Dn0 Sn2		Sy2 Sn2 Dn2			Sy1 Sn0 Dn0	Sy1Sn0 Dn0			Sy0 Sn0 Dn1		Sy3 Sn0 Dn1	Sy1 Sn0 Dn0
4				Dy3 Dn1 Sn0		Sy1 Sn1 Dn0	Sy1Sn0 Dn1			Sy1 Sn0 Dn0					
5					Dy3 Dn0 Sn1			Sy1 Sn0 Dn0						Sy1 Sn0 Dn0	
6						Dy6 Dn0 Sn4	Sy1 Sn0 Dn0	Sy0 Sn0 Dn2	Sy3 Sn2 Dn0	Sy0 Sn1 Dn0		Sy2 Sn2 Dn1		Sy3 Sn0 Dn1	Sy1Sn0 Dn0
7							Dy5 Dn0 Sn2	Sy1 Sn0 Dn0		Sy1Sn0 Dn1		Sy0 Sn0 Dn1			
8								Dy3 Dn1 Sn2	Sy0 Sn2 Dn1	Sy0 Sn1 Dn1		Sy4 Sn2 Dn2		Sy3 Sn0 Dn0	Sy2 Sn0 Dn0
9									Dy7 Dn2 Sn1	Sy1Sn0 Dn1		Sy1 Sn2 Dn0		Sy1 Sn0 Dn0	Sy1 Sn0 Dn0
10										Dy6 Dn1 Sn4		Sy1 Sn0 Dn0			
11											Dy2 Dn0 Sn0				
12												Dy4 Dn2 Sn6		Sy0 Sn0 Dn1	Sy0 Sn0 Dn1
13													Dy2 Dn0 Sn0		
14														Dy6 Dn1 Sn1	Sy2 Sn0 Dn1
15															

Fig. 4.6

### Line symbol pairs

Matrix showing the distribution of discrimination confusions in 21 tests.

$$\begin{array}{|c|} \hline \text{Wy1 Wn1} \\ \hline \text{Rn1} \\ \hline \end{array} = \begin{array}{|c|} \hline \text{Dy1 Dn1} \\ \hline \text{Sn1} \\ \hline \end{array} \text{ or } \begin{array}{|c|} \hline \text{Sy1 Sn1} \\ \hline \text{Dn1} \\ \hline \end{array} \begin{array}{|c|} \hline 3x \quad 2x \\ \hline 1x \\ \hline \end{array}$$

**Wy** = confident confusion

**Wn** = non-confident confusion

**Rn** = non-confident non-confusion

**3 x Wy**

**2 x Wn**

**1 x Rn**

The number of confusions without including a confidence measure was calculated by adding **Wy** and **Wn**. The results were entered into the confusion matrix in Fig. 4.9.

The number of confusions including a confidence measure was calculated by multiplying the different classes of discrimination confusions by an arbitrary grade. The sum of these grades was entered into the confusion matrix in Fig. 4.12.



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Dy1 Dn0 Sn1	Sy1 Sn0 Dn0	Sy0 Sn0 Dn1			Sy0 Sn0 Dn1		Sy1 Sn0 Dn0			Sy0 Sn0 Dn1			Sy0 Sn1 Dn0	
2		Dy0 Dn1 Sn0	Sy1 Sn0 Dn2					Sy1 Sn0 Dn0		Sy0 Sn0 Dn1			Sy0 Sn0 Dn1		Sy1 Sn0 Dn0
3			Dy6 Dn0 Sn1					Sy0 Sn1 Dn0			Sy2 Sn0 Dn1	Sy1 Sn2 Dn0	Sy1 Sn2 Dn0		Sy3 Sn1 Dn2
4				Dy2 Dn0 Sn1		Sy1 Sn0 Dn1	Sy4 Sn1 Dn1		Sy1 Sn0 Dn0		Sy0 Sn0 Dn1			Sy0 Sn0 Dn1	
5					Dy3 Dn0 Sn0	Sy1 Sn0 Dn0			Sy1 Sn0 Dn0					Sy6 Sn0 Dn1	
6						Dy4 Dn0 Sn0	Sy1 Sn3 Dn0	Sy0 Sn0 Dn1			Sy1 Sn0 Dn0				Sy0 Sn0 Dn1
7							Dy2 Dn0 Sn3			Sy0 Sn0 Dn1	Sy1 Sn0 Dn0				
8								Dy1 Dn0 Sn2						Sy1 Sn0 Dn1	
9									Dy3 Dn0 Sn1						
10										Dy1 Dn0 Sn0					
11											Dy4 Dn0 Sn1	Sy0 Sn0 Dn1	Sy0 Sn0 Dn2		Sy3 Sn2 Dn1
12												Dy2 Dn0 Sn4	Sy2 Sn3 Dn0		Sy2 Sn0 Dn0
13													Dy2 Dn0 Sn3		
14														Dy2 Dn2 Sn2	
15															Dy1 Dn0 Sn0

**Fig. 4.7**

**Texture symbol pairs**

Matrix showing the distribution of discrimination confusions in 21 tests.

$$\begin{array}{|c|c|} \hline \text{Wy1 Wn1} \\ \hline \text{Rn1} \\ \hline \end{array} = \begin{array}{|c|c|} \hline \text{Dy1 Dn1} \\ \hline \text{Sn1} \\ \hline \end{array} \text{ or } \begin{array}{|c|c|} \hline \text{Sy1 Sn1} \\ \hline \text{Dn1} \\ \hline \end{array} \quad \begin{array}{|c|c|} \hline 3x \quad 2x \\ \hline 1x \\ \hline \end{array}$$

**Wy** = confident confusion

**Wn** = non-confident confusion

**Rn** = non-confident non-confusion

3 x **Wy**

2 x **Wn**

1 x **Rn**

The number of confusions without including a confidence measure was calculated by adding **Wy** and **Wn**. The results were entered into the confusion matrix in Fig. 4.10

The number of confusions including a confidence measure was calculated by multiplying the different classes of discrimination confusions by an arbitrary grade. The sum of these grades was entered into the confusion matrix in Fig. 4.13.



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3	2					2								
2		4					1						3		
3			2		4			1	1					3	1
4				4		2	1			1					
5					3			1						1	
6						6	1		5	1		4		3	1
7							5	1		1					
8								4	2	1		6		3	2
9									9	1		3		1	1
10										7		1			
11											2				
12												6			
13													2		
14														7	2
15															

Fig. 4.9

Line symbol pairs

Matrix showing the number  
of discrimination confusions  
in 21 tests.

Right:

Performance ranking based on  
the total number of confusions  
of each symbol in all of its  
315 occurrences, arranged by  
(a) symbol number and  
(b) confusion score.

1	(7)	2	(11)
2	(10)	5	(13)
3	(12)	7	(1)
4	(8)	7	(15)
5	(9)	8	(4)
6	(23)	9	(5)
7	(12)	10	(2)
8	(21)	12	(3)
9	(23)	12	(7)
10	(13)	13	(10)
11	(2)	20	(12)
12	(20)	20	(14)
13	(5)	21	(8)
14	(20)	23	(6)
15	(7)	23	(9)



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1						1						1	
2		1	1					1							1
3			6					1			2	3	3		4
4				2		1	5		1						
5					3	1			1					6	
6						4	4				1				
7							2				1				
8								1						1	
9									3						
10										1					
11											4				5
12												2	5		2
13													2		
14														4	
15															1

**Fig. 4.10**  
**Texture symbol pairs**  
 Matrix showing the number  
 of discrimination confusions  
 in 21 tests.

Right:  
 Performance ranking based on  
 the total number of confusions  
 of each symbol in all of its  
 315 occurrences, arranged by  
 (a) symbol number and  
 (b) confusion score.

1	(4)	1	(10)
2	(5)	4	(1)
3	(20)	5	(2)
4	(9)	5	(8)
5	(11)	5	(9)
6	(11)	9	(4)
7	(12)	10	(13)
8	(5)	11	(5)
9	(5)	11	(6)
10	(1)	12	(7)
11	(13)	12	(12)
12	(12)	12	(14)
13	(10)	13	(11)
14	(12)	13	(15)
15	(13)	20	(3)



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	6														
2		11			1		1				1		1		1
3			21		4	9			1			1		3	
4				8	3	9		3					1	1	6
5					10					4		3		6	8
6						15		1		6					6
7							13				2	3			3
8								9	3		4		3	12	3
9									10	1			2	4	
10										3	5				
11											7		4	3	10
12												19	3	1	3
13													12		
14														17	3
15															9

Fig. 4.11

Point symbol pairs

Matrix showing the number of discrimination confusions, in alliance with a confidence measure, in 21 tests.

Right:

Performance ranking , including a confidence measure, based on the total number of graded confusions of each symbol in all of its 315 occurrences, arranged by (a) symbol number and (b) confusion score.

1	(6)	6	(1)
2	(16)	16	(2)
3	(39)	19	(10)
4	(31)	21	(9)
5	(39)	24	(7)
6	(46)	26	(13)
7	(24)	31	(4)
8	(38)	33	(12)
9	(21)	36	(11)
10	(19)	38	(8)
11	(36)	39	(3)
12	(33)	39	(5)
13	(26)	46	(6)
14	(50)	50	(14)
15	(54)	54	(15)



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	8	6					5								
2		13	1				2						10		
3			8		12			3	3			1		10	3
4				11		5	4			3					
5					10			3						3	
6						22	3	2	13	2		11		10	3
7							20	3		4		1			
8								13	5	3		18		9	6
9									26	4		7		3	3
10										24		3			
11											6				
12												22		1	1
13													7		
14														20	7
15															

Fig. 4.12

Line symbol pairs

Matrix showing the number of discrimination confusions, in alliance with a confidence measure, in 21 tests.

Right:

Performance ranking, including a confidence measure, based on the total number of graded confusions of each symbol in all of its 315 occurrences, arranged by (a) symbol number and (b) confusion score.

1	(19)	6	(11)
2	(32)	17	(13)
3	(41)	19	(1)
4	(23)	23	(4)
5	(28)	23	(15)
6	(71)	28	(5)
7	(42)	32	(2)
8	(65)	41	(3)
9	(64)	42	(7)
10	(43)	43	(10)
11	(6)	63	(14)
12	65	64	(9)
13	(17)	65	(8)
14	(63)	65	(12)
15	(23)	71	(6)



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	4	3	1			1		3			1			2	
2		2	5					3		1			1		3
3			19					2			7	7	7		13
4				7		4	15		3		1			1	
5					9	3			3					19	
6						12	9	1			3				1
7							9			1	3				
8								5						4	
9									10						
10										3					
11											13	1	2		14
12												10	12		6
13													9		
14														12	
15															3

Fig. 4.13

*Texture symbol pairs*

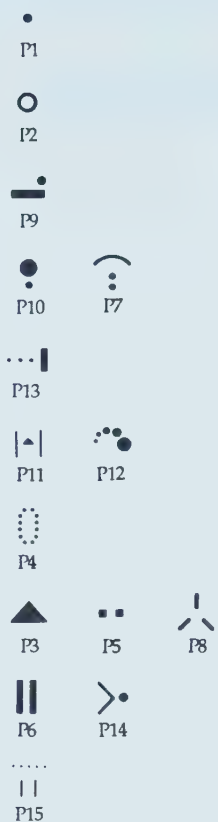
*Matrix showing the number of discrimination confusions, in alliance with a confidence measure, in 21 tests.*

*Right:*

*Performance ranking, including a confidence measure, based on the total number of graded confusions of each symbol in all of its 315 occurrences, arranged by (a) symbol number and (b) confusion score.*

1	(15)	5	(10)
2	(18)	15	(1)
3	(61)	16	(9)
4	(31)	18	(2)
5	(34)	18	(8)
6	(34)	31	(4)
7	(37)	31	(13)
8	(18)	34	(5)
9	(16)	34	(6)
10	(5)	36	(12)
11	(45)	37	(7)
12	(36)	38	(14)
13	(31)	40	(15)
14	(38)	45	(11)
15	(40)	61	(3)





**Fig. 4.14**  
**Performance ranking of**  
**point symbols; confusions only**  
*(shown at 50% actual size)*



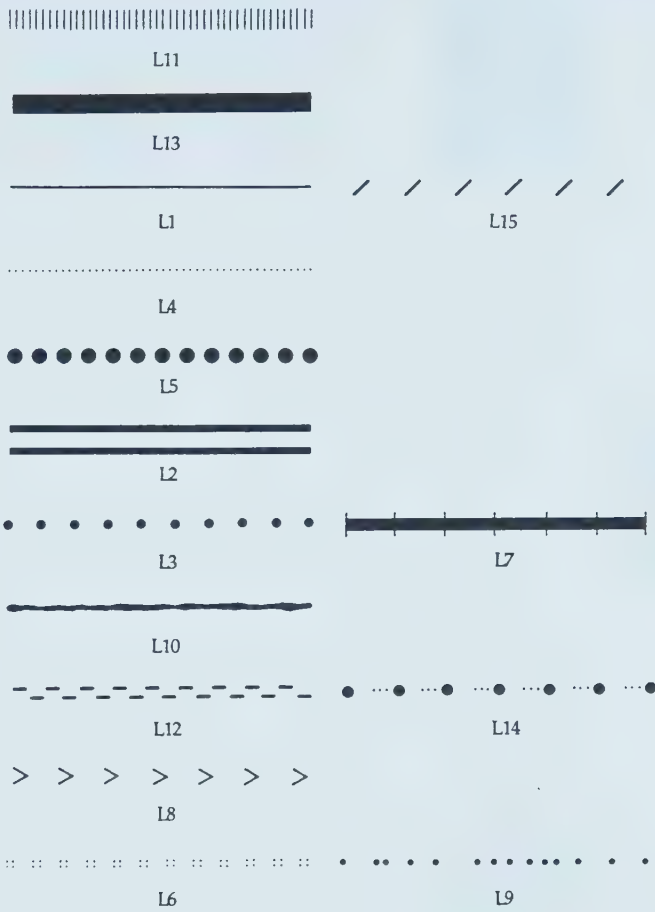
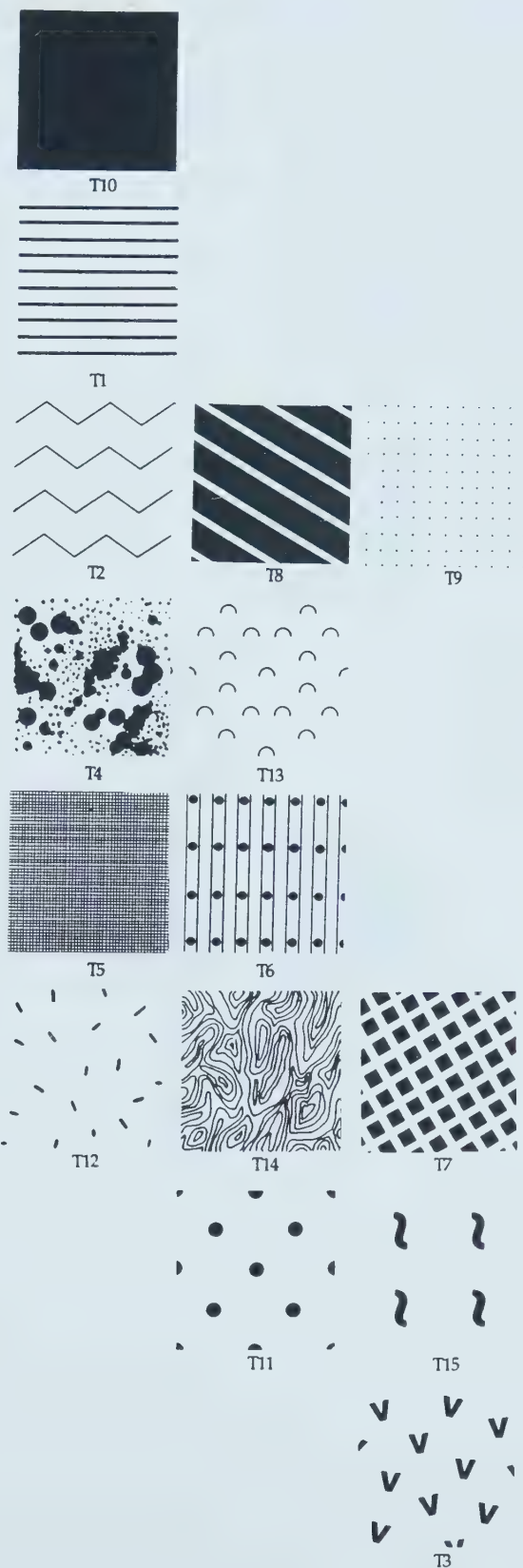


Fig. 4.15  
 Performance ranking of  
 line symbols; confusions only  
 (shown at 50% actual size)





**Fig. 4.16**  
**Performance ranking of**  
**texture symbols; confusions only**  
**(shown at 50 % actual size)**



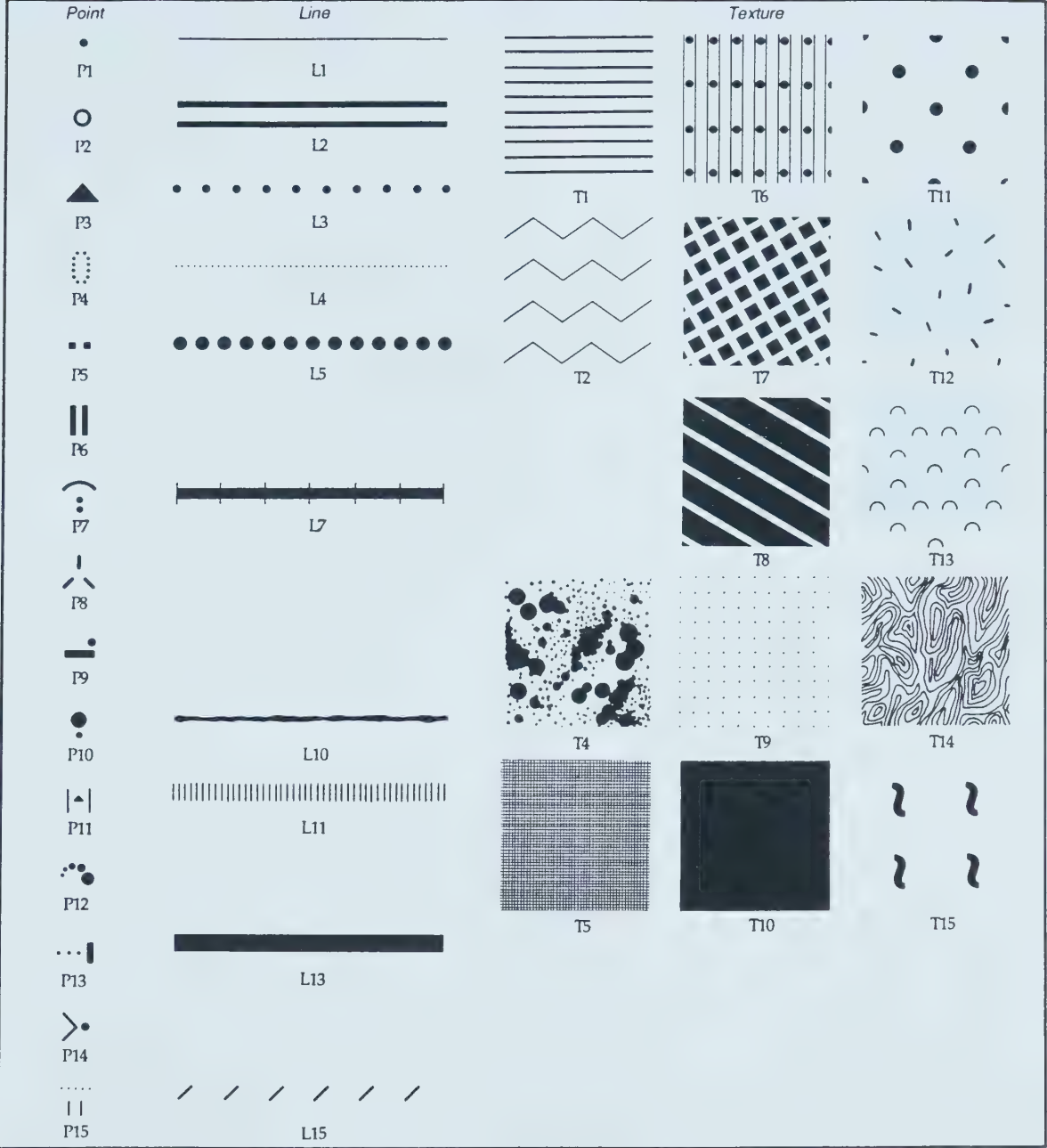
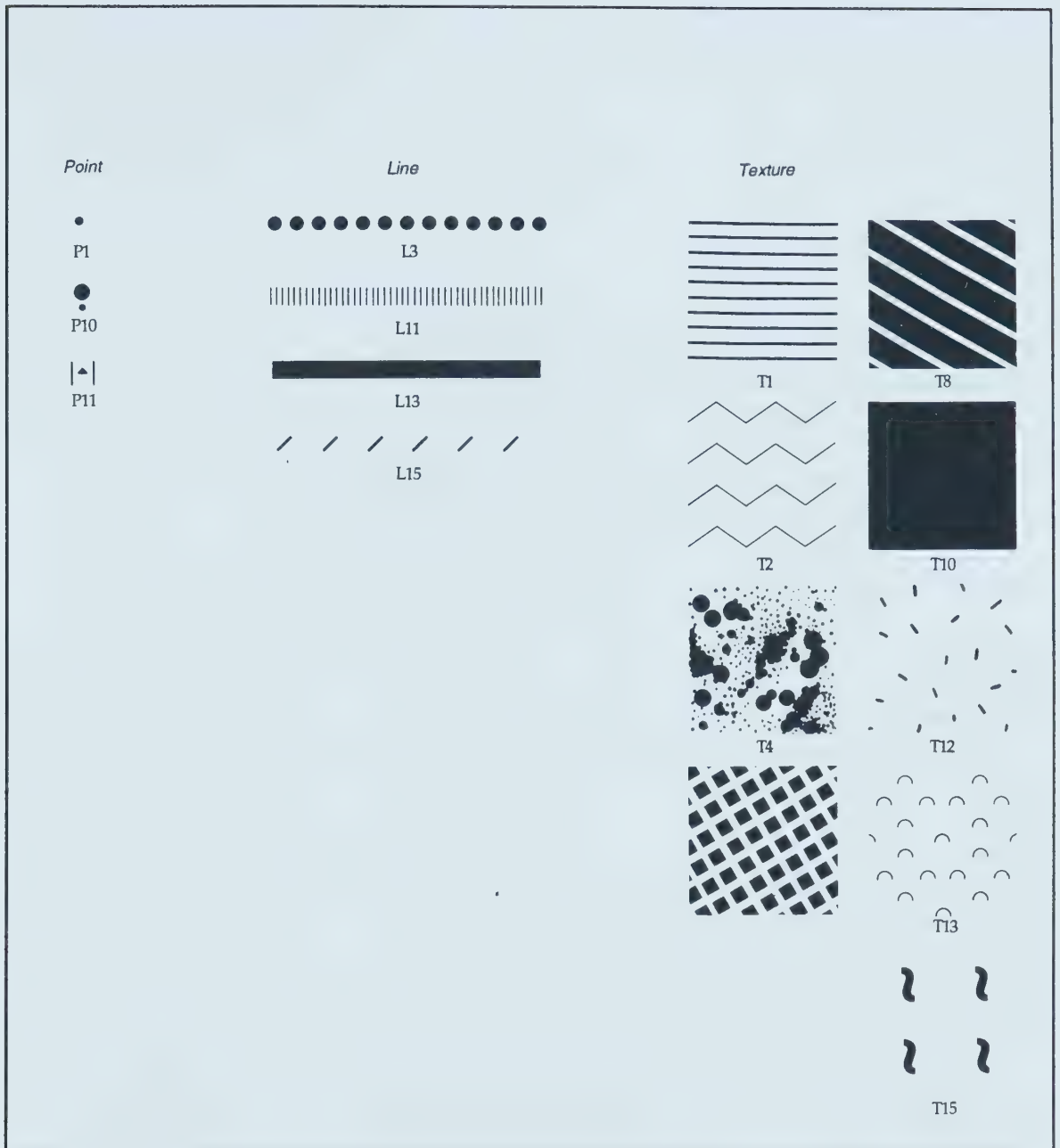


Fig. 4.17  
Proposed symbols discriminable  
in 95 % of total occurrences





**Fig. 4.18**  
*Proposed symbols discriminable  
 according to the criteria of Nolan  
 and Morris (1971)*



It is not apparent how personal differences in test subjects may have physically and perceptually affected their discrimination of the tactile symbols. All of the available information that could affect discrimination was collected during these tests. Visual status, Braille reading experience, age and sex of each of the test subjects was noted as well as the random order of pair presentation and the order of tests done by subjects who completed two or three different tests. These variables were not being tested specifically, however, and only some very general subjective observations will be made here.

When subjects were confident in their responses, they required less time to complete a test. However, the time taken to finish one test was not indicative of the frequency of confusion in symbol comparisons. One subject completed all of the point symbol pair comparisons with no confusion in 20 minutes while another did the task without confusion in 120 minutes.

Subjects employed a variety of strategies to actively examine the test pairs. These can be divided generally into three categories: sequential, simultaneous and combined. Sequential examination was characterized by the use of fingers of one hand to explore both symbols or to guide the exploration of the other. Simultaneous examination was characterized by the use of fingers of both hands to scan the details of both symbols in the pair at the same time, usually in the same direction. Confusion occurred when some line and texture symbols were scanned simultaneously in opposite directions, creating a mirror-image effect. This indicates that symbols with asymmetrical configurations or irregular rhythms may cause discrimination problems for some individuals. Some subjects employed both sequential and simultaneous strategies to gain optimum information or to counter-balance an apparent difference in perception when using the fingers of either their left or right hand.

Discriminability of symbols seemed to depend largely on the recognition of individual symbol features. Some subjects came to quick decisions that seemed to be based on a sensory response, while others



appeared to apply rigorous and analytical problem-solving techniques until they became confident with their decision. 4.11

Many sighted and visually impaired subjects were able to identify symbols that were displayed time after time. From their comments, it was evident that the ability to visualize, memorize or otherwise internalize symbols was directly related to the ability to recognize them. Subjects described specific traits of tactile symbols which make them discriminable or recognizable. These are summarized below:

#### *Point symbols*

Subjects reported a preference for simple configurations with features that can be easily identified. Although it was not intended, rotation was a perceived symbol variable, particularly in symbols with radiating arms.

#### *Line symbols*

Subjects sometimes read the irregular rhythm of features in line symbols as a directional cue. They also sometimes confused line symbols with each other when they read them using a mirror-image scanning strategy.

#### *Texture symbols*

Mirror-image reading also caused confusion for subjects in the discrimination of texture symbols as well as line symbols. The perception of texture symbols appeared to be related either to the sensation of the tactile symbol or to the identification of individual features.

#### *General comments*

Identification of symbols seemed to be satisfying for many subjects and many responded to aesthetic qualities in the symbols. For, example, line symbol L6 was described as a pleasing symbol more than once. It featured regular, densely



arranged short vertical lines and also ranked at the top of its group for the least number of confusions with itself or any other symbols. Texture symbol T4 was considered to be unpleasant to touch in more than one case. It featured an irregular pattern of dots of different dimensions and elevations, some of which were connected in some way. It ranked fourth in terms of the least number of confusions with itself or any other symbols in all occurrences.

### **Implications**

The discrimination and the recognition of tactile symbols seem to be two very different but related processes which must be addressed in the design and use of maps for the visually impaired. Discrimination seems to be based on a combination of structural and textural features. Recognition appears to be related to the memorization of simple, unique features.

All symbols in the proposed symbol set are legible to different degrees. The matrices and resulting performance ranking facilitate the determination of effective symbol subsets for application in the design of maps. The results of this testing show that while most symbols in the point, line and texture groups are highly discriminable when compared to other symbols, they have a good chance of being confused with themselves. The reason for these self-confusions must be understood. Tests should be developed to measure the recognition of these symbols in actual situations where the symbols must be identified both in a legend and on a map. Recommendations for additional study and testing are outlined in Section 6.



## Application Designing a visual/tactile map

*The symbol set evaluated in Section 4 is applied to the design of a visual/tactile map for the visually impaired. The design method outlined here involved the consideration of criteria for the design of visual/tactile maps in relation to the determination of (1) the specific purpose of the map, (2) the profile of potential users, (3) appropriate content, (4) symbol selection, (5) production, (6) training for use and (7) evaluation. Availability is discussed as well as environmental cues which might be keyed to the map.*

5.1

### **Specific purpose**

One of the needs identified by a group of blind and partially sighted individuals (Orientation and mobility support group meeting, August 1988) is access to information about the specific layout and of bus transfer points. The transit zone at the University of Alberta was chosen as an example of such a situation made more complex by traffic moving freely throughout. In this situation, it is confusing that University to Downtown buses do not leave from the same side of the street or proceed in the same direction. Only a legend of the Downtown buses can be included as bus locations are not constant.

### **User profile**

This map was designed for use by haptically capable, motivated, independent travellers with little or no remaining vision who are non-Braille readers and have knowledge of the configurations of the conventional printed alphabet. Tactile symbols were employed to enhance the visual information available to them.

### **Content**

Information to be contained in the map was determined by surveying the region to be mapped on foot, as suggested by Nolan and Morris (1971). Enough information needed to be included on the map to provide critical information without creating conflicting signals in communication. The following landmarks and hazards were considered necessary to this map: **bus zone, bus shelter, specific bus number**



information, curb breaks, road, crosswalks and the location of adjacent buildings. A reference system of labels and legends was developed. A reference to direction was included.

5.2

### **Symbol selection**

The selection of symbols to be used in the map was based on the discriminability performance as measured by this study and on compatibility with environmental features. The best performing symbols in a group were used to represent the most critical features. Labels in large types were included.

### **Production**

The prototypical map was produced through the photomechanical process onto acetate, hand-embossed and painted from behind (Fig. 5.1). An optimum production method does not yet exist for these types of maps. With intensive testing and experimentation, one could be produced commercially through the embossment, vacuum forming or added texture production processes. Both visual and tactile information would have to be developed for use in these separate processes.

### **Training**

The intended use of this map is to facilitate maneuvering in this specific environment for a specific purpose. For this reason, it is likely that this map would be used at home to learn or memorize the layout prior to travel. This map would require some training from specialists or helpers for optimum efficiency.

### **Availability**

Due to the expense of producing individual maps for specific situations, it is worth considering the development of a complete map system from which segments could be produced as needed.



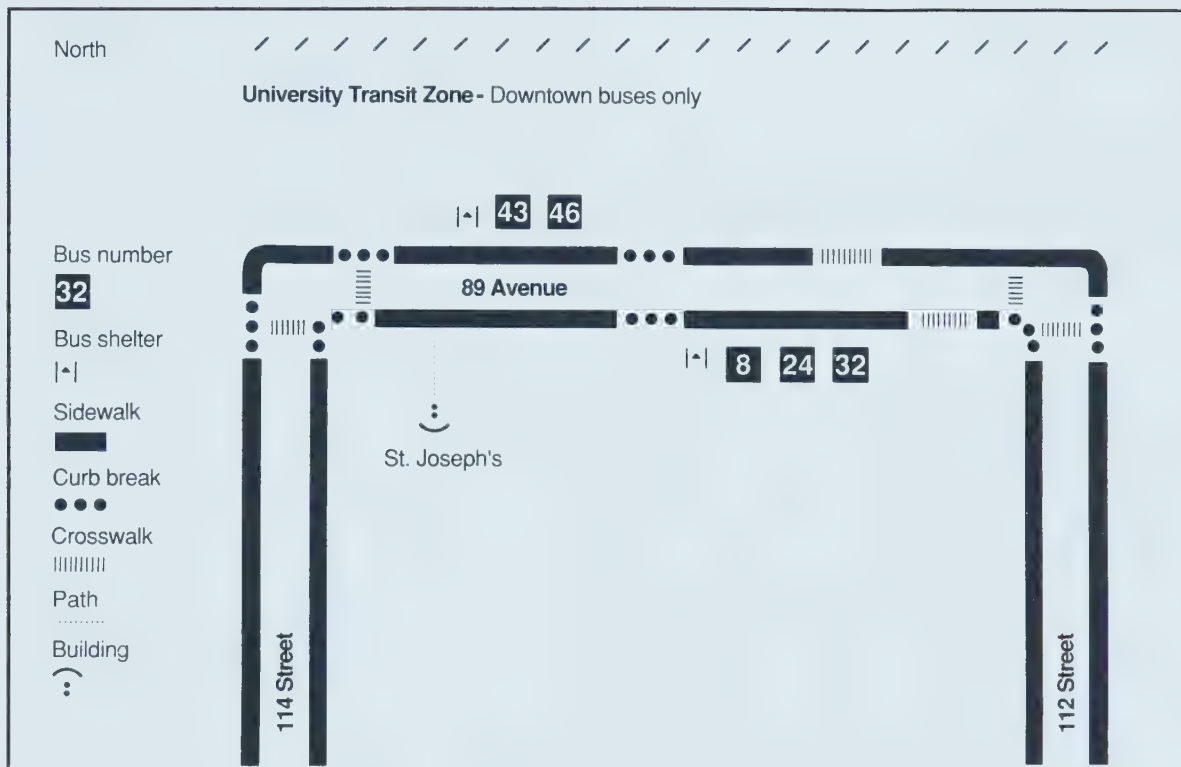
**Environmental cues**

A map of this sort would be most useful if visual and tactile cues would relate the environment to the map. In this way, travellers could check their progress against such things as large embossed signs or changes in texture on their travelling surface.

**Evaluation**

The effectiveness of this prototypical map should be evaluated before it could be produced commercially. Ease of use, in terms of size, information content and symbol discrimination must be determined through interviewing and testing.





**Fig. 5.1**  
**Prototypical map**  
 (Actual size 11 x 17 inches ,  
 shown here at 40 %)



*Recommendations for further testing and study in relation to the design of maps and other information aids for the visually impaired are outlined here within the context of visual communication design and associated disciplines.* 6.1

#### **Proposed symbol set**

The proposed symbols could be improved to increase their discriminability in terms of the elevation, spacing and size of elements. Further testing is required to evaluate the performance of the present symbols in terms of recognition and context. A method of evaluating the compatibility of the proposed symbols with their intended referents should be developed if compatibility is indeed a factor in the discriminability or recognition of tactile symbols. Production methods should be investigated to determine which materials enhance the discriminability of the proposed tactile symbols. The performance of symbol groups in relation to each other must be evaluated in empirical and applied tests to determine highly discriminable combinations.

#### **Application to informational and educational aids**

The map designed for this project should be tested in an actual map reading situation. The application of the tactile symbols to educational aids for the visually impaired should be studied to determine guidelines for improvement. Specifications for training the visually impaired in the use of informational and educational aids must be developed. For example, games employing the proposed symbol set, such as tactile dominoes, could be developed to teach recognition skills. Other games or exercises could be developed to teach efficient scanning strategies.



### **Potential of visual/tactile information**

6.2

The information potential of visual/tactile symbol systems must be studied further, especially in relation to critical situations. Personal information aids for the visually impaired featuring both printed and raised symbols should be studied to determine criteria for the design of personal information aids for the visually impaired. The feasibility of producing maps of bus routes, neighborhoods and cities must be determined to make such aids accessible to the largest number of visually impaired individuals. The installation of raised environmental cues could be considered, with or without reference to maps. Input in the development of improved information aids for the visually impaired must come from potential users in combination with interdisciplinary teams of designers and researchers.



This thesis project report has described the development of a proposed system of tactile symbols intended for use in the design of maps for the visually impaired. Although these tactile symbols were developed for use in maps, they can be applied to the design of other informational and educational aids for the visually impaired. Further study and testing in the area of information aids is recommended in an effort to increase the visually impaired person's access to critical information. This should be done by interdisciplinary teams of potential users, psychologists, cartographers, teachers, orientation and mobility specialists, industrial designers and visual communication designers.



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## *Appendix*

### **A-1**

Initial symbols photo-etched onto 18 x 24 " zinc plates for embossing; also cut into 9 x 12 " panels for vacuum forming. Alphabets included for supplementary study.  
(shown at 40 % actual size)

### **A.2**

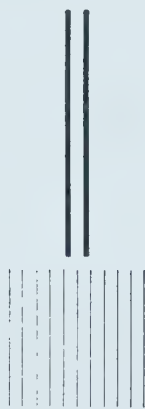
Matrix showing pair identification numbers; applies to point, line and texture groups.

### **A.3 to A.11**

Test response sheets for three random orders in each of the point, line and texture pair comparisons.



-24"-



7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

-12"-

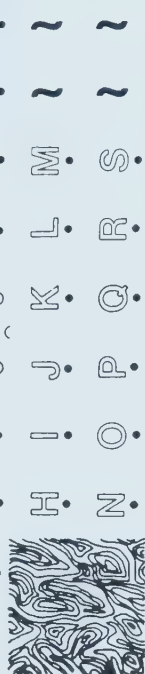


R S T U V W X Y Z 1

-8"-



E F G H I J K L M



2 3 4 5 6 7 8 9 0



symbol number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2		16	17	18	19	20	21	22	23	24	25	26	27	28	29
3			30	31	32	33	34	35	36	37	38	39	40	41	42
4				43	44	45	46	47	48	49	50	51	52	53	54
5					55	56	57	58	59	60	61	62	63	64	65
6						66	67	68	69	70	71	72	74	74	75
7							76	77	78	79	80	81	82	83	84
8								85	86	87	88	89	90	91	92
9									93	94	95	96	97	98	99
10										100	101	102	103	104	105
11											106	107	108	109	110
12												111	112	113	114
13													115	116	117
14														118	119
15															120

A.2

Pair identification numbers



<b>Tactile symbols</b> <hr/> <b>Test 1 2 3</b> Point symbols Random order 1  Date Tester	1:47	SD y n	31:52	SD y n	61:22	SD y n	91:114	SD y n
	2:45	SD y n	32:101	SD y n	62:70	SD y n	92:69	SD y n
	3:46	SD y n	33:94	SD y n	63:8	SD y n	93:102	SD y n
	4:100	SD y n	34:7	SD y n	64:23	SD y n	94:19	SD y n
	5:91	SD y n	35:13	SD y n	65:18	SD y n	95:4	SD y n
	6:119	SD y n	36:112	SD y n	66:108	SD y n	96:78	SD y n
<b>Name?</b>  Sex m f Age? 18-24 25-34 35-44 45-54 55-64 65-74  Vis impaired y n Braille reader? y n	7:50	SD y n	37:54	SD y n	67:58	SD y n	97:59	SD y n <b>A.3</b>
	8:31	SD y n	38:35	SD y n	68:11	SD y n	98:83	SD y n
	9:42	SD y n	39:32	SD y n	69:72	SD y n	99:56	SD y n
	10:65	SD y n	40:9	SD y n	70:89	SD y n	100:26	SD y n
	11:76	SD y n	41:99	SD y n	71:107	SD y n	101:55	SD y n
	12:44	SD y n	42:10	SD y n	72:68	SD y n	102:24	SD y n
	13:2	SD y n	43:106	SD y n	73:84	SD y n	103:92	SD y n
	14:57	SD y n	44:88	SD y n	74:39	SD y n	104:40	SD y n
	15:118	SD y n	45:87	SD y n	75:104	SD y n	105:115	SD y n
	16:28	SD y n	46:90	SD y n	76:67	SD y n	106:15	SD y n
	17:27	SD y n	47:71	SD y n	77:30	SD y n	107:34	SD y n
	18:53	SD y n	48:73	SD y n	78:98	SD y n	108:113	SD y n
	19:82	SD y n	49:16	SD y n	79:64	SD y n	109:81	SD y n
	20:51	SD y n	50:12	SD y n	80:48	SD y n	110:63	SD y n
	21:49	SD y n	51:62	SD y n	81:86	SD y n	111:116	SD y n
	22:38	SD y n	52:80	SD y n	82:66	SD y n	112:117	SD y n
	23:33	SD y n	53:95	SD y n	83:109	SD y n	113:105	SD y n
	24:37	SD y n	54:103	SD y n	84:111	SD y n	114:77	SD y n
Do the samples feel the same or different? SD  Are you confident in your answer? yes or no? y n  Thank you. (BST)	25:97	SD y n	55:93	SD y n	85:1	SD y n	115:14	SD y n
	26:85	SD y n	56:29	SD y n	86:20	SD y n	116:61	SD y n
	27:110	SD y n	57:6	SD y n	87:79	SD y n	117:3	SD y n
	28:75	SD y n	58:96	SD y n	88:21	SD y n	118:5	SD y n
	29:25	SD y n	59:36	SD y n	89:43	SD y n	119:41	SD y n
	30:74	SD y n	60:60	SD y n	90:17	SD y n	120:120	SD y n



<b>Tactile symbols</b>	1:47	SD y n	31:52	SD y n	61:22	SD y n	91:114	SD y n
<b>Test 1 2 3</b>	2:45	SD y n	32:101	SD y n	62:70	SD y n	92:69	SD y n
<b>Line symbols</b>	3:46	SD y n	33:94	SD y n	63:8	SD y n	93:102	SD y n
<b>Random order 1</b>	4:100	SD y n	34:7	SD y n	64:23	SD y n	94:19	SD y n
<b>Date</b>	5:91	SD y n	35:13	SD y n	65:18	SD y n	95:4	SD y n
<b>Tester</b>	6:119	SD y n	36:112	SD y n	66:108	SD y n	96:78	SD y n
<b>Name?</b>	7:50	SD y n	37:54	SD y n	67:58	SD y n	97:59	SD y n <b>A.4</b>
<b>Sex m f</b>	8:31	SD y n	38:35	SD y n	68:11	SD y n	98:83	SD y n
<b>Age?</b>	9:42	SD y n	39:32	SD y n	69:72	SD y n	99:56	SD y n
<b>18-24 25-34</b>	10:65	SD y n	40:9	SD y n	70:89	SD y n	100:26	SD y n
<b>35-44 45-54</b>	11:76	SD y n	41:99	SD y n	71:107	SD y n	101:55	SD y n
<b>55-64 65-74</b>	12:44	SD y n	42:10	SD y n	72:68	SD y n	102:24	SD y n
<b>Vis impaired y n</b>	13:2	SD y n	43:106	SD y n	73:84	SD y n	103:92	SD y n
<b>Braille reader? y n</b>	14:57	SD y n	44:88	SD y n	74:39	SD y n	104:40	SD y n
	15:118	SD y n	45:87	SD y n	75:104	SD y n	105:115	SD y n
	16:28	SD y n	46:90	SD y n	76:67	SD y n	106:15	SD y n
	17:27	SD y n	47:71	SD y n	77:30	SD y n	107:34	SD y n
	18:53	SD y n	48:73	SD y n	78:98	SD y n	108:113	SD y n
	19:82	SD y n	49:16	SD y n	79:64	SD y n	109:81	SD y n
	20:51	SD y n	50:12	SD y n	80:48	SD y n	110:63	SD y n
	21:49	SD y n	51:62	SD y n	81:86	SD y n	111:116	SD y n
	22:38	SD y n	52:80	SD y n	82:66	SD y n	112:117	SD y n
	23:33	SD y n	53:95	SD y n	83:109	SD y n	113:105	SD y n
	24:37	SD y n	54:103	SD y n	84:111	SD y n	114:77	SD y n
<b>Do the samples feel the same or different?</b>	25:97	SD y n	55:93	SD y n	85:1	SD y n	115:14	SD y n
<b>SD</b>	26:85	SD y n	56:29	SD y n	86:20	SD y n	116:61	SD y n
<b>Are you confident in your answer?</b>	27:110	SD y n	57:6	SD y n	87:79	SD y n	117:3	SD y n
<b>yes or no? y n</b>	28:75	SD y n	58:96	SD y n	88:21	SD y n	118:5	SD y n
<b>Thank you. (BST)</b>	29:25	SD y n	59:36	SD y n	89:43	SD y n	119:41	SD y n
	30:74	SD y n	60:60	SD y n	90:17	SD y n	120:120	SD y n



<b>Tactile symbols</b>	1:47	SD y n	31:52	SD y n	61:22	SD y n	91:114	SD y n
<b>Test 1 2 3</b>	2:45	SD y n	32:101	SD y n	62:70	SD y n	92:69	SD y n
<b>Texture symbols</b>	3:46	SD y n	33:94	SD y n	63:8	SD y n	93:102	SD y n
<b>Random order 1</b>	4:100	SD y n	34:7	SD y n	64:23	SD y n	94:19	SD y n
<b>Date</b>	5:91	SD y n	35:13	SD y n	65:18	SD y n	95:4	SD y n
<b>Tester</b>	6:119	SD y n	36:112	SD y n	66:108	SD y n	96:78	SD y n
<b>Name?</b>	7:50	SD y n	37:54	SD y n	67:58	SD y n	97:59	SD y n <b>A.5</b>
<b>Sex m f</b>	8:31	SD y n	38:35	SD y n	68:11	SD y n	98:83	SD y n
<b>Age?</b>	9:42	SD y n	39:32	SD y n	69:72	SD y n	99:56	SD y n
<b>18-24 25-34</b>	10:65	SD y n	40:9	SD y n	70:89	SD y n	100:26	SD y n
<b>35-44 45-54</b>	11:76	SD y n	41:99	SD y n	71:107	SD y n	101:55	SD y n
<b>55-64 65-74</b>	12:44	SD y n	42:10	SD y n	72:68	SD y n	102:24	SD y n
<b>Vis impaired y n</b>	13:2	SD y n	43:106	SD y n	73:84	SD y n	103:92	SD y n
<b>Braille reader? y n</b>	14:57	SD y n	44:88	SD y n	74:39	SD y n	104:40	SD y n
	15:118	SD y n	45:87	SD y n	75:104	SD y n	105:115	SD y n
	16:28	SD y n	46:90	SD y n	76:67	SD y n	106:15	SD y n
	17:27	SD y n	47:71	SD y n	77:30	SD y n	107:34	SD y n
	18:53	SD y n	48:73	SD y n	78:98	SD y n	108:113	SD y n
	19:82	SD y n	49:16	SD y n	79:64	SD y n	109:81	SD y n
	20:51	SD y n	50:12	SD y n	80:48	SD y n	110:63	SD y n
	21:49	SD y n	51:62	SD y n	81:86	SD y n	111:116	SD y n
	22:38	SD y n	52:80	SD y n	82:66	SD y n	112:117	SD y n
	23:33	SD y n	53:95	SD y n	83:109	SD y n	113:105	SD y n
	24:37	SD y n	54:103	SD y n	84:111	SD y n	114:77	SD y n
<b>Do the samples feel the same or different?</b>	25:97	SD y n	55:93	SD y n	85:1	SD y n	115:14	SD y n
<b>SD</b>	26:85	SD y n	56:29	SD y n	86:20	SD y n	116:61	SD y n
<b>Are you confident in your answer?</b>	27:110	SD y n	57:6	SD y n	87:79	SD y n	117:3	SD y n
<b>yes or no? y n</b>	28:75	SD y n	58:96	SD y n	88:21	SD y n	118:5	SD y n
<b>Thank you. (BST)</b>	29:25	SD y n	59:36	SD y n	89:43	SD y n	119:41	SD y n
	30:74	SD y n	60:60	SD y n	90:17	SD y n	120:120	SD y n



<b>Tactile symbols</b>	1:28	SD y n	31:19	SD y n	61:11	SD y n	91:10	SD y n
<b>Test 1 2 3</b>	2:47	SD y n	32:81	SD y n	62:109	SD y n	92:6	SD y n
<b>Point symbols</b>	3:52	SD y n	33:91	SD y n	63:83	SD y n	93:68	SD y n
<b>Random order 2</b>	4:89	SD y n	34:51	SD y n	64:105	SD y n	94:79	SD y n
<b>Date</b>	5:22	SD y n	35:13	SD y n	65:42	SD y n	95:24	SD y n
<b>Tester</b>	6:67	SD y n	36:12	SD y n	66:37	SD y n	96:3	SD y n
<b>Name?</b>	7:114	SD y n	37:18	SD y n	67:32	SD y n	97:2	SD y n <span style="border: 1px solid black; padding: 0 2px;">A.6</span>
<b>Sex m f</b>	8:15	SD y n	38:48	SD y n	68:103	SD y n	98:75	SD y n
<b>Age?</b>	9:45	SD y n	39:4	SD y n	69:72	SD y n	99:106	SD y n
<b>18-24 25-34</b>	10:27	SD y n	40:63	SD y n	70:111	SD y n	100:96	SD y n
<b>35-44 45-54</b>	11:101	SD y n	41:119	SD y n	71:56	SD y n	101:84	SD y n
<b>55-64 65-74</b>	12:71	SD y n	42:49	SD y n	72:77	SD y n	102:21	SD y n
<b>Vis impaired y n</b>	13:70	SD y n	43:112	SD y n	73:65	SD y n	103:92	SD y n
<b>Braille reader? y n</b>	14:30	SD y n	44:62	SD y n	74:97	SD y n	104:5	SD y n
	15:69	SD y n	45:108	SD y n	75:9	SD y n	105:57	SD y n
	16:34	SD y n	46:86	SD y n	76:93	SD y n	106:25	SD y n
	17:46	SD y n	47:78	SD y n	77:90	SD y n	107:88	SD y n
	18:53	SD y n	48:116	SD y n	78:1	SD y n	108:36	SD y n
	19:94	SD y n	49:50	SD y n	79:26	SD y n	109:39	SD y n
	20:73	SD y n	50:38	SD y n	80:14	SD y n	110:43	SD y n
	21:8	SD y n	51:54	SD y n	81:76	SD y n	111:40	SD y n
	22:98	SD y n	52:80	SD y n	82:85	SD y n	112:41	SD y n
	23:102	SD y n	53:58	SD y n	83:99	SD y n	113:118	SD y n
	24:113	SD y n	54:66	SD y n	84:29	SD y n	114:74	SD y n
<b>Do the samples feel the same or different?</b>	25:100	SD y n	55:59	SD y n	85:107	SD y n	115:87	SD y n
<b>SD</b>	26:82	SD y n	56:117	SD y n	86:20	SD y n	116:60	SD y n
<b>Are you confident in your answer?</b>	27:7	SD y n	57:31	SD y n	87:55	SD y n	117:104	SD y n
<b>yes or no? y n</b>	28:16	SD y n	58:33	SD y n	88:61	SD y n	118:17	SD y n
<b>Thank you. (BST)</b>	29:23	SD y n	59:35	SD y n	89:44	SD y n	119:115	SD y n
	30:64	SD y n	60:95	SD y n	90:110	SD y n	120:120	SD y n



<b>Tactile symbols</b>	1:28	SD	y	n	31:19	SD	y	n	61:11	SD	y	n	91:10	SD	y	n	
	2:47	SD	y	n	32:81	SD	y	n	62:109	SD	y	n	92:6	SD	y	n	
<b>Test 1 2 3</b>	3:52	SD	y	n	33:91	SD	y	n	63:83	SD	y	n	93:68	SD	y	n	
<b>Line symbols</b>	4:89	SD	y	n	34:51	SD	y	n	64:105	SD	y	n	94:79	SD	y	n	
<b>Random order 2</b>	5:22	SD	y	n	35:13	SD	y	n	65:42	SD	y	n	95:24	SD	y	n	
Date	6:67	SD	y	n	36:12	SD	y	n	66:37	SD	y	n	96:3	SD	y	n	
Tester																	
<b>Name?</b>	7:114	SD	y	n	37:18	SD	y	n	67:32	SD	y	n	97:2	SD	y	n	<u>A.7</u>
Sex m f	8:15	SD	y	n	38:48	SD	y	n	68:103	SD	y	n	98:75	SD	y	n	
Age?	9:45	SD	y	n	39:4	SD	y	n	69:72	SD	y	n	99:106	SD	y	n	
18-24 25-34	10:27	SD	y	n	40:63	SD	y	n	70:111	SD	y	n	100:96	SD	y	n	
35-44 45-54	11:101	SD	y	n	41:119	SD	y	n	71:56	SD	y	n	101:84	SD	y	n	
55-64 65-74	12:71	SD	y	n	42:49	SD	y	n	72:77	SD	y	n	102:21	SD	y	n	
Vis impaired y n																	
Braille reader? y n																	
	13:70	SD	y	n	43:112	SD	y	n	73:65	SD	y	n	103:92	SD	y	n	
	14:30	SD	y	n	44:62	SD	y	n	74:97	SD	y	n	104:5	SD	y	n	
	15:69	SD	y	n	45:108	SD	y	n	75:9	SD	y	n	105:57	SD	y	n	
	16:34	SD	y	n	46:86	SD	y	n	76:93	SD	y	n	106:25	SD	y	n	
	17:46	SD	y	n	47:78	SD	y	n	77:90	SD	y	n	107:88	SD	y	n	
	18:53	SD	y	n	48:116	SD	y	n	78:1	SD	y	n	108:36	SD	y	n	
	19:94	SD	y	n	49:50	SD	y	n	79:26	SD	y	n	109:39	SD	y	n	
	20:73	SD	y	n	50:38	SD	y	n	80:14	SD	y	n	110:43	SD	y	n	
	21:8	SD	y	n	51:54	SD	y	n	81:76	SD	y	n	111:40	SD	y	n	
	22:98	SD	y	n	52:80	SD	y	n	82:85	SD	y	n	112:41	SD	y	n	
	23:102	SD	y	n	53:58	SD	y	n	83:99	SD	y	n	113:118	SD	y	n	
	24:113	SD	y	n	54:66	SD	y	n	84:29	SD	y	n	114:74	SD	y	n	
Do the samples feel the same or different?	25:100	SD	y	n	55:59	SD	y	n	85:107	SD	y	n	115:87	SD	y	n	
SD	26:82	SD	y	n	56:117	SD	y	n	86:20	SD	y	n	116:60	SD	y	n	
Are you confident in your answer?	27:7	SD	y	n	57:31	SD	y	n	87:55	SD	y	n	117:104	SD	y	n	
yes or no? y n	28:16	SD	y	n	58:33	SD	y	n	88:61	SD	y	n	118:17	SD	y	n	
Thank you. (BST)	29:23	SD	y	n	59:35	SD	y	n	89:44	SD	y	n	119:115	SD	y	n	
	30:64	SD	y	n	60:95	SD	y	n	90:110	SD	y	n	120:120	SD	y	n	



<b>Tactile symbols</b>	1:28	SD y n	31:19	SD y n	61:11	SD y n	91:10	SD y n
	2:47	SD y n	32:81	SD y n	62:109	SD y n	92:6	SD y n
<b>Test 1 2 3</b>	3:52	SD y n	33:91	SD y n	63:83	SD y n	93:68	SD y n
<b>Texture symbols</b>	4:89	SD y n	34:51	SD y n	64:105	SD y n	94:79	SD y n
<b>Random order 2</b>	5:22	SD y n	35:13	SD y n	65:42	SD y n	95:24	SD y n
Date	6:67	SD y n	36:12	SD y n	66:37	SD y n	96:3	SD y n
Tester								
<b>Name?</b>	7:114	SD y n	37:18	SD y n	67:32	SD y n	97:2	SD y n <b>A.8</b>
Sex m f	8:15	SD y n	38:48	SD y n	68:103	SD y n	98:75	SD y n
Age?	9:45	SD y n	39:4	SD y n	69:72	SD y n	99:106	SD y n
18-24 25-34	10:27	SD y n	40:63	SD y n	70:111	SD y n	100:96	SD y n
35-44 45-54	11:101	SD y n	41:119	SD y n	71:56	SD y n	101:84	SD y n
55-64 65-74	12:71	SD y n	42:49	SD y n	72:77	SD y n	102:21	SD y n
Vis impaired y n								
Braille reader? y n								
	13:70	SD y n	43:112	SD y n	73:65	SD y n	103:92	SD y n
	14:30	SD y n	44:62	SD y n	74:97	SD y n	104:5	SD y n
	15:69	SD y n	45:108	SD y n	75:9	SD y n	105:57	SD y n
	16:34	SD y n	46:86	SD y n	76:93	SD y n	106:25	SD y n
	17:46	SD y n	47:78	SD y n	77:90	SD y n	107:88	SD y n
	18:53	SD y n	48:116	SD y n	78:1	SD y n	108:36	SD y n
	19:94	SD y n	49:50	SD y n	79:26	SD y n	109:39	SD y n
	20:73	SD y n	50:38	SD y n	80:14	SD y n	110:43	SD y n
	21:8	SD y n	51:54	SD y n	81:76	SD y n	111:40	SD y n
	22:98	SD y n	52:80	SD y n	82:85	SD y n	112:41	SD y n
	23:102	SD y n	53:58	SD y n	83:99	SD y n	113:118	SD y n
	24:113	SD y n	54:66	SD y n	84:29	SD y n	114:74	SD y n
Do the samples feel the same or different?	25:100	SD y n	55:59	SD y n	85:107	SD y n	115:87	SD y n
SD	26:82	SD y n	56:117	SD y n	86:20	SD y n	116:60	SD y n
Are you confident in your answer?	27:7	SD y n	57:31	SD y n	87:55	SD y n	117:104	SD y n
yes or no? y n	28:16	SD y n	58:33	SD y n	88:61	SD y n	118:17	SD y n
Thank you. (BST)	29:23	SD y n	59:35	SD y n	89:44	SD y n	119:115	SD y n
	30:64	SD y n	60:95	SD y n	90:110	SD y n	120:120	SD y n



**Tactile symbols****Test 1 2 3**

Point symbols

Random order 3

Date

Tester

Name?

Sex m f

Age?

18-24 25-34

35-44 45-54

55-64 65-74

Vis impaired y n

Braille reader? y n

Do the samples feel the  
same or different?

SD

Are you confident in  
your answer?

yes or no? y n

Thank you. (BST)

1:69	SD	y	n	31:63	SD	y	n	61:90	SD	y	n	91:118	SD	y	n
2:30	SD	y	n	32:117	SD	y	n	62:73	SD	y	n	92:34	SD	y	n
3:64	SD	y	n	33:77	SD	y	n	63:12	SD	y	n	93:81	SD	y	n
4:70	SD	y	n	34:61	SD	y	n	64:80	SD	y	n	94:116	SD	y	n
5:23	SD	y	n	35:5	SD	y	n	65:103	SD	y	n	95:105	SD	y	n
6:108	SD	y	n	36:120	SD	y	n	66:29	SD	y	n	96:14	SD	y	n
7:71	SD	y	n	37:114	SD	y	n	67:96	SD	y	n	97:3	SD	y	n
8:16	SD	y	n	38:102	SD	y	n	68:60	SD	y	n	98:41	SD	y	n
9:62	SD	y	n	39:4	SD	y	n	69:52	SD	y	n	99:19	SD	y	n
10:95	SD	y	n	40:59	SD	y	n	70:94	SD	y	n	100:78	SD	y	n
11:101	SD	y	n	41:56	SD	y	n	71:13	SD	y	n	101:83	SD	y	n
12:7	SD	y	n	42:55	SD	y	n	72:54	SD	y	n	102:26	SD	y	n
13:112	SD	y	n	43:92	SD	y	n	73:32	SD	y	n	103:24	SD	y	n
14:35	SD	y	n	44:115	SD	y	n	74:99	SD	y	n	104:40	SD	y	n
15:9	SD	y	n	45:67	SD	y	n	75:106	SD	y	n	105:86	SD	y	n
16:27	SD	y	n	46:98	SD	y	n	76:47	SD	y	n	106:109	SD	y	n
17:82	SD	y	n	47:48	SD	y	n	77:53	SD	y	n	107:1	SD	y	n
18:49	SD	y	n	48:66	SD	y	n	78:51	SD	y	n	108:79	SD	y	n
19:33	SD	y	n	49:111	SD	y	n	79:38	SD	y	n	109:43	SD	y	n
20:97	SD	y	n	50:20	SD	y	n	80:37	SD	y	n	110:11	SD	y	n
21:110	SD	y	n	51:21	SD	y	n	81:85	SD	y	n	111:89	SD	y	n
22:45	SD	y	n	52:17	SD	y	n	82:75	SD	y	n	112:68	SD	y	n
23:100	SD	y	n	53:22	SD	y	n	83:74	SD	y	n	113:39	SD	y	n
24:119	SD	y	n	54:8	SD	y	n	84:28	SD	y	n	114:93	SD	y	n
25:31	SD	y	n	55:18	SD	y	n	85:46	SD	y	n	115:6	SD	y	n
26:65	SD	y	n	56:58	SD	y	n	86:91	SD	y	n	116:36	SD	y	n
27:44	SD	y	n	57:72	SD	y	n	87:50	SD	y	n	117:10	SD	y	n
28:57	SD	y	n	58:107	SD	y	n	88:42	SD	y	n	118:88	SD	y	n
29:15	SD	y	n	59:84	SD	y	n	89:76	SD	y	n	119:25	SD	y	n
30:113	SD	y	n	60:104	SD	y	n	90:2	SD	y	n	120:87	SD	y	n

A.9



<b>Tactile symbols</b>	1:69	SD y n	31:63	SD y n	61:90	SD y n	91:118	SD y n
<b>Test 1 2 3</b>	2:30	SD y n	32:117	SD y n	62:73	SD y n	92:34	SD y n
<b>Line symbols</b>	3:64	SD y n	33:77	SD y n	63:12	SD y n	93:81	SD y n
<b>Random order 3</b>	4:70	SD y n	34:61	SD y n	64:80	SD y n	94:116	SD y n
<b>Date</b>	5:23	SD y n	35:5	SD y n	65:103	SD y n	95:105	SD y n
<b>Tester</b>	6:108	SD y n	36:120	SD y n	66:29	SD y n	96:14	SD y n
<b>Name?</b>	7:71	SD y n	37:114	SD y n	67:96	SD y n	97:3	SD y n <span style="border: 1px solid black; padding: 0 2px;">A.10</span>
<b>Sex m f</b>	8:16	SD y n	38:102	SD y n	68:60	SD y n	98:41	SD y n
<b>Age?</b>	9:62	SD y n	39:4	SD y n	69:52	SD y n	99:19	SD y n
<b>18-24 25-34</b>	10:95	SD y n	40:59	SD y n	70:94	SD y n	100:78	SD y n
<b>35-44 45-54</b>	11:101	SD y n	41:56	SD y n	71:13	SD y n	101:83	SD y n
<b>55-64 65-74</b>	12:7	SD y n	42:55	SD y n	72:54	SD y n	102:26	SD y n
<b>Vis impaired y n</b>	13:112	SD y n	43:92	SD y n	73:32	SD y n	103:24	SD y n
<b>Braille reader? y n</b>	14:35	SD y n	44:115	SD y n	74:99	SD y n	104:40	SD y n
	15:9	SD y n	45:67	SD y n	75:106	SD y n	105:86	SD y n
	16:27	SD y n	46:98	SD y n	76:47	SD y n	106:109	SD y n
	17:82	SD y n	47:48	SD y n	77:53	SD y n	107:1	SD y n
	18:49	SD y n	48:66	SD y n	78:51	SD y n	108:79	SD y n
	19:33	SD y n	49:111	SD y n	79:38	SD y n	109:43	SD y n
	20:97	SD y n	50:20	SD y n	80:37	SD y n	110:11	SD y n
	21:110	SD y n	51:21	SD y n	81:85	SD y n	111:89	SD y n
	22:45	SD y n	52:17	SD y n	82:75	SD y n	112:68	SD y n
	23:100	SD y n	53:22	SD y n	83:74	SD y n	113:39	SD y n
	24:119	SD y n	54:8	SD y n	84:28	SD y n	114:93	SD y n
<b>Do the samples feel the same or different?</b>	25:31	SD y n	55:18	SD y n	85:46	SD y n	115:6	SD y n
<b>SD</b>	26:65	SD y n	56:58	SD y n	86:91	SD y n	116:36	SD y n
<b>Are you confident in your answer?</b>	27:44	SD y n	57:72	SD y n	87:50	SD y n	117:10	SD y n
<b>yes or no? y n</b>	28:57	SD y n	58:107	SD y n	88:42	SD y n	118:88	SD y n
<b>Thank you. (BST)</b>	29:15	SD y n	59:84	SD y n	89:76	SD y n	119:25	SD y n
	30:113	SD y n	60:104	SD y n	90:2	SD y n	120:87	SD y n



**Tactile symbols**

Test 1 2 3  
Texture symbols  
Random order 3

Date  
Tester

1:69	SD y n	31:63	SD y n	61:90	SD y n	91:118	SD y n
2:30	SD y n	32:117	SD y n	62:73	SD y n	92:34	SD y n
3:64	SD y n	33:77	SD y n	63:12	SD y n	93:81	SD y n
4:70	SD y n	34:61	SD y n	64:80	SD y n	94:116	SD y n
5:23	SD y n	35:5	SD y n	65:103	SD y n	95:105	SD y n
6:108	SD y n	36:120	SD y n	66:29	SD y n	96:14	SD y n

Name?

Sex m f  
Age?  
18-24 25-34  
35-44 45-54  
55-64 65-74

Vis impaired y n  
Braille reader? y n

7:71	SD y n	37:114	SD y n	67:96	SD y n	97:3	SD y n	A.11
8:16	SD y n	38:102	SD y n	68:60	SD y n	98:41	SD y n	
9:62	SD y n	39:4	SD y n	69:52	SD y n	99:19	SD y n	
10:95	SD y n	40:59	SD y n	70:94	SD y n	100:78	SD y n	
11:101	SD y n	41:56	SD y n	71:13	SD y n	101:83	SD y n	
12:7	SD y n	42:55	SD y n	72:54	SD y n	102:26	SD y n	

13:112	SD y n	43:92	SD y n	73:32	SD y n	103:24	SD y n
14:35	SD y n	44:115	SD y n	74:99	SD y n	104:40	SD y n
15:9	SD y n	45:67	SD y n	75:106	SD y n	105:86	SD y n
16:27	SD y n	46:98	SD y n	76:47	SD y n	106:109	SD y n
17:82	SD y n	47:48	SD y n	77:53	SD y n	107:1	SD y n
18:49	SD y n	48:66	SD y n	78:51	SD y n	108:79	SD y n

19:33	SD y n	49:111	SD y n	79:38	SD y n	109:43	SD y n
20:97	SD y n	50:20	SD y n	80:37	SD y n	110:11	SD y n
21:110	SD y n	51:21	SD y n	81:85	SD y n	111:89	SD y n
22:45	SD y n	52:17	SD y n	82:75	SD y n	112:68	SD y n
23:100	SD y n	53:22	SD y n	83:74	SD y n	113:39	SD y n
24:119	SD y n	54:8	SD y n	84:28	SD y n	114:93	SD y n

Do the samples feel the  
same or different?  
SD

Are you confident in  
your answer?  
yes or no? y n

Thank you. (BST)

25:31	SD y n	55:18	SD y n	85:46	SD y n	115:6	SD y n
26:65	SD y n	56:58	SD y n	86:91	SD y n	116:36	SD y n
27:44	SD y n	57:72	SD y n	87:50	SD y n	117:10	SD y n
28:57	SD y n	58:107	SD y n	88:42	SD y n	118:88	SD y n
29:15	SD y n	59:84	SD y n	89:76	SD y n	119:25	SD y n
30:113	SD y n	60:104	SD y n	90:2	SD y n	120:87	SD y n







**Panel text  
from final visual  
presentation**



## Thesis project

This exhibition documents the design of a proposed system of tactile symbols for use in the design of maps for the visually impaired.

These symbols could also be applicable to the design of other information aids for the visually impaired.

*Please touch.*



# *Introduction*



## Terms

*Visually impaired* describes people with a variety of visual disabilities whose level of usable vision ranges from partial to non-existent. *Blind* refers to individuals having no functional sight.

*Visual* pertains to the sense of sight, and *tactile and haptic*, to the active, exploratory sense of touch.

*Orientation aid* denotes any information device, such as a map, which enables people to function or travel confidently in any environment.

*Map* describes a graphic representation of spatial configurations generally indicated with point, line and area symbols.

*Graphic* refers to marks or characters made on a printed or raised surface.



## **Method**

This exhibition is arranged in four parts, which correspond to the design method used in this thesis project.



## *Background*

Visual communication designers are responsible for developing graphic materials to facilitate the perception of needed information. When conventional printed aids are not usable, for example, by individuals with visual impairments, alternative designs must be developed. Information which can be perceived through both vision and touch is one way of extending access to critical information for the visually impaired.



## *Problem*

Orientation is a critical information problem for individuals with low vision. Researchers and potential users agree that graphic orientation aids, such as maps, which provide both printed and raised information are useful tools in learning spatial concepts and in planning travel routes. However, few of these visual/tactile maps are actually used when they are available. The design, production and training in use of these maps must be studied to determine how they could be improved.

In this project, the design of visual/tactile maps was analyzed to determine areas for improvement. The presentation of the tactile information in maps for the visually impaired was studied in particular. One factor possible affecting the effectiveness of maps for the visually impaired, is that tactile symbols are often converted from conventional printed graphics and not designed specifically for tactile discrimination.



## *Proposal*

A system of 45 tactile surfaces consisting of 15 point, 15 line and 15 texture symbols was developed for use in the design of maps for the visually impaired. These symbols were generated in consideration of criteria collected mainly from empirical studies on tactile perception. These symbols were tested for discriminability and graded in terms of performance to provide a means of selection for use in maps.



## *Application*

A sample map which incorporates some of these symbols in combination was designed to demonstrate how the results of this project might be applied. Recommendations for further study, testing and application have been outlined to provide starting points for further development in the design of information for the visually impaired.



# *Background*

*Information aids for the visually impaired*



## **Designing critical information**

One of the most significant challenges to visual communication designers in association with specialists in other disciplines, is to develop materials that will extend the human ability to perceive and use critical information, that which is essential to an individual's health, safety and general well-being. Safety instruction manuals, food and drug labels, transportation schedules and travel maps are a few of the aids that people can consult to find critical information.



## **Alternatives to conventional aids**

Alternative modes of information retrieval are required for the visually impaired when restrictions in vision interfere with their ability to use conventional aids which cater to the fully sighted.



## **Visual impairment**

About one in every hundred Canadians is visually impaired. Of these, only about one third are considered legally blind, meaning having less than 10% of normal vision.

Visual impairment can result from birth defects, accident or disease. Many diseases causing low vision occur later in life and therefore affect more seniors than other age groups.



Visual impairment can be characterized as two basic condition, the loss of visual acuity and the loss of field of vision.

The loss of visual acuity affects the sharpness of vision and results in seeing blurred images. This is commonly called blurred vision and affects 90% of visually impaired Canadians.

The loss of field of vision affects the whole view when looking straight ahead and is commonly called tunnel vision because peripheral vision is blurred or lost. In other cases, a blind spot may occur in the middle of the visual field. The loss of field of vision affects 10% of visually impaired Canadians.



The extent to which the loss of vision affects a person's normal functioning depends on the severity of the impairment and how much vision he or she actually requires to perform specific tasks.



*Sometimes equality means treating people the same, despite their differences, and sometimes it means treating them as equals by accommodating their differences.*

*R. S. Abella*



Visually impaired individuals must continually attempt to fit into a world that generally accommodates vision. They are encouraged to make use of their remaining vision to access visual information.

Many blind and partially sighted people learn to use perceptual alternatives to vision to gather information about their environment through the sense of hearing, the sense of smell and the sense of touch.



*Man has not seen a thing who has not  
felt it.*

*H. D. Thoreau*



## **Vision and touch**

Visually impaired people can use aspects of both their visual and haptic senses to access critical information. They can use the sense of touch to guide their vision or to verify impressions gained through the sense of touch.

The inclusion of both printed and raised information then would be appropriate in some information aids for the visually impaired.

Vision and touch are very different in nature, however, and simple conversion from visual images to raised ones is not suitable.



Every part of the visually impaired persons's environment can be enhanced through the positive effects of colour, space and texture, and their knowledge of their environment can be increased through the use of relevant information aids.

If designers are aware of the special information needs of the visually impaired, they might be able to provide them with viable means of complementing or substituting their remaining vision.



## **Orientation and the visually impaired**

Orientation is one of the greatest difficulties faced by visually impaired people.

Personal effectiveness is decreased by an inability to travel independently, safely and purposefully. To achieve independent travel, visually impaired travellers must have the ability to discover critical spatial arrangements. Spatial ability increases with mobility training, the use of effective orientation aids and subsequent travel experience.



# *Problem*

*Improving maps for the visually impaired*



*Orientation aids are tools to be used by visually impaired persons to develop or enhance their understanding of basic spatial relationships, to facilitate their comprehension of specific travel environments, to refresh their memory of routes and areas, to further their skill in independent route planning, to enable them to travel independently in unfamiliar areas, and to add to their enjoyment of physical space.*

*B. L. Bentzen*



## Graphic orientation aids

In addition to promoting independent travel, orientation aids can promote increased awareness of spatial concepts. Orientation aids fall into three categories: models, graphic aids and verbal aids. Graphic aids present information in tactile, visual or tactile *and* visual form. Maps, a type of graphic orientation aid, may be used in appropriate cases to teach spatial concepts or may be used independently, after initial training, for route planning. Although graphic aids are not suitable for people with restricted tactile sensitivity, they were important to those visually impaired individuals who have difficulty following verbal instructions and who require a better understanding of spatial concepts than can be gained through verbal descriptions. Graphic aids augment effective mobility training and may be used in combination with other orientation aids.



## **Visual/tactile maps**

Maps which include visual and tactile information have been promoted by researchers as having the greatest communication potential for the largest number of visually impaired individuals. When both printed and embossed, these visual/tactile maps can be read by the visually impaired and their helpers. These maps are inconspicuous because they look like conventional aids and are more economical than maps designed for people with specific vision problems or the totally blind because they can be used by individuals with various levels of visual impairment. Persons with residual vision have been found to make use of both printed and raised information to the extent that they are able. For example, partially sighted individuals can use their residual vision to guide their tactile exploration.



The use of such maps is supported by the visually impaired who have specific orientation problems to solve. Any aspect of the environment of the visually impaired can be mapped, including intersections, floor plans and transportation systems. In a discussion with a group of visually impaired and blind individuals, specific mapping needs were reported, namely the layout of specific intersections, bus transfer points, unfamiliar rooms (including furniture arrangement) and streets with building entrances marked. Environmental cues such as raised international symbols for washrooms would be indispensable.

For motivated individuals with some haptic capability, visual/tactile maps appear to present excellent alternatives to conventional orientation aids. **In situations where such maps are available, why are so few actually used?**



## **Design and production**

The physical and perceptual uses of maps for the visually impaired are affected by their design, production and training.

Discrepancies have been noted relating to visual/tactile maps that may impede the development of coherent principles for their design and production and may ultimately affect their appeal and use. Some of these are outlined briefly here.

Although many psychologists and cartographers have addressed the problem of designing maps for the visually impaired, no studies on the subject have been found with input from industrial or visual communication designers. The relationship of content and function is central to the problem of developing effective maps for the visually impaired. For the most part, maps for many purposes are made by hand and there is no control over the quality of design and production.



Even apparently well designed maps are inadequate without effective training.

Enough environmental details must be included on the map to provide a wealth of information to the visually impaired user, but not enough to cause tactile clutter. The size of the map should be small enough to accommodate comfortable scanning with the hands, but large enough to include the large symbol sizes required for tactile discrimination.

Production materials affect not only the discrimination of map symbols, but also the physical use of the map. Maps which are to be consulted en route must be portable, flexible and durable, yet the thin plastics that might match these criteria sometimes affect the legibility of the symbols. Symbols printed on plastic often become distorted or rub off. Maps produced from embossing paper are more economical to produce than their plastic counterparts, but do not wear as well.



The sighted and the visually impaired have different ways of dealing with their environments, yet maps for the visually impaired are often simply converted from existing layouts that were originally intended for use by the fully sighted.



## *Visual information*

The design of visual information in visual/tactile maps must be perceptible by low vision users. Many potential low vision users do not read Braille. Although printed materials and conventional symbols may be used as an alternative, they must be redesigned to be visually useful to those with impaired sight. This may be as easy as using a bold typeface and as complicated as determining the optimum type size for legibility. Colour may be used for contrast, but it is difficult to predict how it will be perceived by those with widely varying visual disabilities. Materials providing enough reflectance may also facilitate contrast, although glare must be avoided.



## *Tactile information*

The design of tactile information in visual/tactile maps must be based on principles of tactile perception and discrimination. If partially sighted and blind persons are to be encouraged to make use of the sense of touch for perception, information aids prepared for them must provide for optimum discriminability, recognition and ease of use. Visual information cannot be merely converted to tactile information.



*Maps specifically designed for the visually impaired possess tremendous potential to enhance their learning of spatial concepts and to facilitate their planning of travel routes. For those individuals with haptic capability but restricted visual ability, effective tactile symbols can complement or replace printed counterparts. The design of such visual/tactile maps must extend beyond converting existing printed configurations to tactile form. Effective tactile symbols should be systematically developed specifically to facilitate the tactile perception of information.*



## **Discriminable tactile symbols**

Many tactile symbols that have been used as test materials for the design of maps for the visually impaired have suffered from being tactile versions of conventional printed graphics. The practice of using visual criteria to select tactile symbols severely limits the number and variety of tactile symbols that could be potentially useful to the visually impaired. That practice also restricts the development and testing of optimal new forms which might, for example, be more compatible or easily associated with the landmarks that they would represent.



# *Proposal*

*Designing a system of tactile map symbols*



*In sight, information is perceived holistically, while in touch, information is perceived sequentially. This increases the difficulty of the tactile scanning of maps and the recognition of map symbols. Strategies for use will differ with every person as will their cognitive abilities. Every effort must be made in the design of these maps to enhance the discrimination and recognition of tactile symbols.*



## Criteria for the design of tactile symbols

Criteria for the development of discriminable and recognizable tactile symbols may be gathered from the numerous studies done in the areas of tactile perception and tactile symbol discrimination.

The conventional symbol groups used in maps for the sighted and the visually impaired are known as point, line and area. Point symbols normally represent landmarks, line symbols normally represent trails or boundaries and area symbols normally represent regions of space.

In this project, area symbols are referred to as texture symbols since this more aptly describes the raised patterns developed.



## *Contrast*

Symbols should differ from each other in as many ways as possible, and at least 25% to 30% in size. Visual contrast does not provide a good indication of tactile contrast. **Point** symbols should differ from each other in terms of shape, size, elevation, and outline. **Line** symbols should differ from each other in terms of delineation, dimension, roughness and frequency. **Texture** symbols should differ from each other in terms of intensity, density, interval and the size, shape and direction of components.

## *Complexity*

Maps should be simple and not cluttered with too many symbols. The smallest discriminable symbols should be used to accomplish this. Overuse of texture symbols should be avoided as it causes tactile noise.



### *Compatibility*

The configuration of the symbol used should be easily associated with the information it represents, wherever possible.

Double lines are easily associated with roads, for example. Rough textures could be used to represent uneven travelling surfaces.

### *Shape*

Shape recognition is one of the most difficult tactile tasks, but it is made easier by the use of small scale symbols.

### *Delineation*

It is difficult to discriminate small outline shapes, especially when they are smaller than 1.2 cm in diameter.

### *Traceability*

Line symbols must be designed so that they are easily traced or followed. The use of double lines allows for better tracking than one if the lines are separated by 3.1 to 6.3 mm.



## *Dimension*

Tactile symbols must be much larger than visual symbols to facilitate perception. Point symbols should be small enough to fit under the fingertips. The minimum discriminable line length is from 12.7 to 25.4 mm, depending on the pattern. Texture symbols with outer dimensions of 5 cm x 5 cm are easily distinguished and smaller symbols with a 2.0 cm dimension are often discriminable. Small scale elements in texture symbols are easier to distinguish than large scale ones.

## *Elevation*

Tactile edges can be easily discriminated and intensity facilitates tactile perception. Differences in the intensity of texture elements are more easily perceived than the shape or orientation of elements. A discriminable elevation for point symbols is 0.85 - 1.52 mm and 1.02 mm for line and texture symbols.



### *Proximity*

Textures should not interfere with point or line symbols when used together.

### *Intersection*

The intersection of lines is discriminable if the lines are notably different and if one line is broken at the point of intersection.

### *Spacing*

There should be a minimum space of 2.3 to 3.8 mm between point symbols. The spacing between dots in a line identifies lines, but the spacing between dashes in a line does not.

### *Orientation*

For direction to be a discriminable feature, the scanning of texture symbols must occur in many directions. Orientation should not be used as a discriminable feature in point or texture symbols.



## *Indexing*

Adding Braille labels often increases problems of tactile clutter. Information may be presented on an underlay or overlay such as the grid margins or other reference devices. Map legends should occupy a standard location.



## Developing a proposed symbol system

### *Taxonomy of symbol features*

A programme for generating point, line and texture symbol features was developed in consideration of the formal guidelines suggested above. A taxonomy chart was devised which classified the following basic features and configurations of abstract symbols: *symbol group, frequency of features, shape of features, dimensions of features, elevation of features, delineation of features, configuration of features, relationship between features, rhythm of features, density of features and orientation of features.*

### *Generation of symbols*

Numerous possible symbols were generated by combining various features of the taxonomy chart. Guidelines for dimension and spacing were considered in the choice of symbol configurations comprising a testable set.



### *Selection and production of acceptable symbols*

Fifteen symbols in each of the point, line and texture groups were selected among dozens of generated symbols as those which comprised the set with the most contrast between symbols. These, along with some alternatives, were rendered graphically for photo-reproduction to be used in the photo-etching process. Symbols featured thin lines to accommodate the change of line thickness that would occur in the production process.

The symbols were photo-etched into two 18 x 24 inch zinc plates with nitric acid, one to a minimum depth of approximately 0.5 mm and one to a maximum depth of approximately 1.0 mm.



These plates were used to test symbol impression in both the vacuum forming and mechanical embossing processes. Neither process gave an optimal result in terms of impression, so an initial symbol set was hand-embossed onto coated Iconofix paper by pressing styluses of different widths into the etched zinc plates. (Further testing would be required to determine the best mechanical process for symbol production.)

The hand-embossed symbols were then inspected informally through the sense of touch to determine a potentially effective set for testing. Refinements were made based on further informal tactile observations. A final set of hand-embossed symbols was prepared. From these 240 point symbols, 240 line symbols and 240 texture symbols, testing materials for pair comparisons were prepared.



## Testing the proposed symbol set

The objective of the testing was to evaluate the relative discriminability of a proposed tactile symbol set of 15 point, 15 line and 15 texture surfaces to determine which subsets could be used in the design of maps for the visually impaired.



## **Method**

The relative performance of symbols was tested in a series of pair comparisons by sighted and visually impaired subjects, who examined the symbol pairs through the sense of touch with their hands under a vision barrier. Three random orders of the 120 possible pairs were balanced over twenty-one comparisons undertaken in each of the three symbol groups. Subjects were asked to judge if each symbol in each pair was the same or different from the other. For an allied measurement, they were also asked whether they were confident in their answer. No time limit was imposed and subjects were encouraged to take breaks as needed.



## Subjects

Thirty-eight volunteer sighted, partially sighted and blind subjects participated in the testing. They were between 18 and 64 years old and varied widely in education and vocation. Twenty-one of the 35 sighted subjects were female, 14 were male. The partially sighted subject was male. Of the 2 blind subjects, one was female, one was male. None of the sighted subjects had any training in reading Braille. The partially sighted subject used optic aids daily to extend his remaining vision and did not use Braille materials, although he was trained to read them. The two blind subjects maintained their skill in reading Braille. A large number of tactually inexperienced sighted subjects were involved due to the small number of available, visually impaired persons. The haptic abilities of blind subjects do not vary greatly from those of sighted subjects.



## Materials

Fifteen surfaces in each of the point, line and texture groups were developed according to the programme described in the last section. Test materials were prepared by hand-embossing 16 copies of each of the proposed 45 symbols onto coated paper, using photo-etched zinc plates as masters. The resulting 120 symbols pairs in the point, line and texture groups were numbered for ease of identification and arrangement according to their position on a master matrix of pair comparisons. For each of the symbol groups, test pair tiles were prepared to accommodate the comparison between each symbol with itself and all other symbols in its group. Each pair of embossed symbols was glued to lightweight tiles made of Fomecor, a presentation material consisting of pressed foam, covered on both sides with coated paper. The tiles were stored in an upright position in trays for easy access.



### *Point symbol pair tiles*

Each point symbol was hand-embossed onto the centre of a 2.5 x 2.5 cm square of Iconofix coated paper. Each of the 120 required symbol pairs was glued to one face of a 7.5 x 2.5 x 0.5 cm Fomecor tile, separated by an area of 2.5 x 2.5 cm.

### *Line symbol pair tiles*

Each line symbol was hand-embossed onto the horizontal centre of a 10.0 x 5.0 cm rectangle of Iconofix coated paper. Each of the 120 required line pairs was glued to one face of a 22.5 x 5.0 x 0.5 cm Fomecor tile, separated by an area of 2.5 x 5.0 cm.

### *Texture symbol pair tiles*

Each texture symbol was hand-embossed onto the entire surface of a 5.0 x 5.0 cm square of Iconofix coated paper. Each of the 120 required texture pairs was glued to one face of a 12.5 x 5.0 x 0.5 cm Fomecor tile, separated by an area of 2.5 x 5.0 cm.



### *Vision barrier*

A vision barrier was designed to ensure that the symbol pairs would be inspected through touch alone by the sighted and partially sighted subjects. It was not used with the two completely blind subjects, who depended wholly on the sense of touch for discrimination. Four notched Fomecor panels were fitted together to form the structure, which resembled a table top lectern and sloped down towards the seated subject. The base of the barrier supported the structure and featured a cut-out guide which held the pair tiles in place while subjects examined the embossed surfaces actively with their fingertips. Subjects were able to place their hands under the low front opening, which was wide enough to accommodate free hand movement, but low and long enough to obstruct their view of the pair tiles and of their hands. A high and wide opening at the back allowed the experimenter access to the tile guide, but concealed the placement of the pair tiles from the subjects.



### *Response sheets*

Nine forms were designed to accommodate answers to the questions of comparison and confidence for all symbol pairs tested, in three random orders of three symbol groups. The questions were arranged in rows of six to provide an easily searched array for the experimenter to monitor the pair orders and mark responses. These forms were easily scanned for analysis after the testing.



## **Procedure**

The testing was done in rooms that offered as little distraction as possible. Subjects were asked to sit facing the experimenter and in front of the vision barrier, which rested on a table. They were encouraged to assume a comfortable position. After the first test by the first subject, an office chair was replaced by a more comfortable drafting chair.

A prepared statement was read to each subject prior to the testing which briefly described the test.

To familiarize themselves with the testing set-up, subjects were invited to or physically guided to place their hands under the vision barrier on the first pair tile to be compared. The vision barrier was moved as needed to facilitate comfortable sitting position when arms were extended for pair examination under the barrier.



Seven tests were completed in each of the first, second and third random orders for the point, line and texture symbol pair comparisons. In each of 21 tests for each symbol group, 120 possible pairs were compared, one after the other, according to the relevant random pair order. Each pair tile was taken from the front of the point, line or texture tile tray and placed in the tile guide on the base of the vision barrier.

Subjects were permitted to examine the pair tiles out of the guide as long as the tiles remained under the vision barrier. The two totally blind subjects examined the pair tiles without the vision barrier or tile guide.



In each pair comparison, the subjects were asked whether the symbols felt the same or different and if they were confident in their response. After the first few questions, most subjects responded without needing the questions; "same-yes", "same-no", "different-yes", or "different-no". It was not insisted that subjects wait for the questions because the questions annoyed some subjects by delaying their responses.

The two-part response for each pair comparison was circled next to the pair number on the response sheet. As soon as a response was given for each pair, the pair tile was taken out of the guide and placed at the back of the tile tray to keep a consistent arrangement for the next text with the same random order.



The experimenter was required to check every pair number on the tiles against the order on the response sheet to ensure that the responses were noted correctly for each symbol pair. No time limit was imposed and breaks were encouraged, but rarely taken. The time required for comparing 120 pairs in any symbol group varied from 15 minutes to 120 minutes. The average test time, without breaks, was approximately 35 minutes.

At the end of each test, subjects were asked if they had any comments to make and if they had not already done three tests, whether they were interested in participating in another symbol test. Subjects were not permitted to see the pairs unless they were not intending to participate in any more tests.



## **Discussion of test results**

Two types of data were collected during the pair comparisons: quantitative scores that were based on frequencies of confusion and qualitative notations that were based on general observations.

## **Performance ranking**

Based on the test results collected, two confusion matrices were prepared for each of the point, line and texture groups. One type showed only the frequencies of confusion and the other showed frequencies of confusion in alliance with confidence factors. These were used in two different methods to determine scores for ranking the relative performance of individual symbols.



### *Confusions only*

In the first ranking method, the relative performance of individual symbols was determined by calculating the total number of confusions for each symbol in all of its occurrences. (Each symbol was presented 15 times in 21 tests for a total number of 315 occurrences.) Symbols were ranked according to the number of times that they were confused with themselves or other symbols in all of their occurrences.



### *Confusions with confidence measure*

In the second ranking method, an allied confidence measure was recorded and considered in addition to simple frequency counts. A confusion score was determined by attaching an arbitrary grade to confusions which ranged, in descending order, from most significant to least significant.

A "confusion with confidence" response was assigned a grade of 3.

A "confusion without confidence" response was assigned a grade of 2.

A "non-confusion without confidence" response was assigned a grade of 1.

A "non-confusion with confidence" response was assigned a grade of 0.



### *Other measures*

Further arbitrary measures may be applied to determine a quantitative threshold of relative discriminability of the proposed symbols.

All 15 point symbols, 10 of the 15 line symbols and 14 of the 15 texture symbols met the criteria of being discriminable in more than 95% of the 315 total occurrences.

If we were to apply the strict criteria that the confusion of a symbol with itself or other symbols must be 10% or less, then the number of acceptable symbols would be drastically reduced. This could be due to the high number of confusions that occurred when symbols were compared to themselves.



## *Self-confusion*

This high self-confusion phenomenon might relate to differences in function between the fingers of the left and right hands and to problems in manufacturing identical copies. Some researchers reported this phenomenon in tests with visually impaired grade-school children and suggested that it might be due to the subjects' concentrating on finding differences in comparison. They proposed that subjects would look for likeness instead of difference in a map reading situation. This phenomenon has been found in other studies and has apparently still not been fully investigated or understood.



Regardless of performance ranking, no symbols were discarded, since only a small subset of any symbol group would be employed in maps for the visually impaired. In this way, no potentially effective combinations were overlooked. Symbols which did not perform well in combination with the other 14 in the group can still be effective in certain smaller subsets.



## **General observations**

It is not apparent how personal differences in test subjects may have physically and perceptually affected their discrimination of the tactile symbols. All available information that could affect discrimination was collected during these tests. Visual status, Braille reading experience, age and sex of each of the test subjects was noted as well as the random order of pair presentation and the order of tests done by subjects who completed two or three different tests. These variations were not being tested specifically, however, and only some very general subjective observations will be made here.



### *Scanning strategies*

Subjects employed a variety of strategies to actively examine the test pairs. Sequential examination was characterized by the use of the fingers of one hand to explore both symbols or by the use of the fingers of one hand to guide the exploration of the other. Simultaneous examination was characterized by the use of the fingers of both hands to scan the details of both symbols in the pair at the same time, usually in the same direction. Confusion occurred when some line and texture symbols were scanned simultaneously in opposite directions, creating a mirror-image effect. This indicates that symbols with asymmetrical configurations or irregular rhythms may cause discrimination problems for some individuals. Some subjects employed both sequential and simultaneous strategies to gain optimum information or to counterbalance an apparent difference in perception when using the fingers of their left or right hand.



### *Discriminability and recognition*

The discriminability of symbols seemed to depend largely on the recognition of individual symbol features and the subject's decision-making process. Some subjects came to quick decisions that seemed to be based on sensory response, while others appeared to apply rigorous and analytical problem-solving techniques until they were confident with their decision.

Many sighted and visually impaired subjects were able to identify symbols that were displayed time after time. From their comments, it was evident that the ability to visualize, memorize or otherwise internalize symbols and their components was directly related to the ability to recognize them.



### *Point symbols*

Subjects reported a preference for simple configurations with features that can be easily identified. Although it was not intended, rotation was a perceived symbol variable, particularly in symbols with radiating arms.

### *Line symbols*

Subjects sometimes read the irregular rhythm of features in line symbols as a directional cue. They also sometimes confused line symbols with each other when they read them using a mirror-image scanning strategy.

### *Texture symbols*

Mirror-image reading also caused confusion for subjects in the discrimination of texture symbols. The perception of texture symbols appeared to be related either to the sensation of the tactile symbols or to the identification of individual features.



## **Implications**

The discrimination and the recognition of tactile symbols seem to be two very different but related processes which must be addressed in the design and use of maps for the visually impaired.

Discrimination seems to be based on a combination of structural and textural features. Recognition appears to be related to the memorization of simple, unique features.

All of the symbols in the proposed symbol set are legible to different degrees. The matrices and resulting performance ranking facilitate the determination of effective symbol subsets for application in the design of maps.



The results of this testing show that while most symbols in the point, line and texture groups are highly discriminable when compared to other symbols, they have a good chance of being confused with themselves. The reason for these self-errors must be understood. Tests should be developed to measure the recognition of these symbols in actual situations where the symbols must be identified both in a legend and on a map. Given the uncertainties concerning the self-error phenomenon reported in tests similar to this one, the strictest measure would not be applied to the selection of all symbols for use in maps. However, it would be considered in selecting symbols to represent hazards or critical landmarks. Additional criteria for the selection of symbols would be based on their compatibility with the environmental features that they would represent.

Recommendations are outlined in the next section.



## **Recommendations**

Recommendations for further testing and study in relation to the design of maps and other information aids for the visually impaired are outlined here.



### *Proposed symbol set*

The proposed symbols could be improved to increase their discriminability in terms of the elevation, spacing and size of elements. Further testing is required to evaluate the performance of the symbols in terms of recognition and context. A method of evaluating the compatibility of the proposed symbols with their intended referents should be developed if compatibility is indeed a factor in the discriminability or recognition of tactile symbols. Production methods should be investigated to determine which materials enhance the discriminability of the proposed tactile symbols. The performance of symbol groups in relation to each other must be evaluated in empirical and applied tests to determine combinations that are highly discriminable.



### *Application to informational and educational aids*

The map designed for this project should be tested in an actual map reading situation. The application of the tactile symbols to educational aids for the visually impaired should be studied to determine guidelines for improvement. Specifications for training the visually impaired in the use of informational and educational aids must be developed. For example, games employing the proposed symbol set, such as tactile dominoes, could be developed to teach recognition skills. Other games or exercises could be developed to teach optimal scanning strategies.



### *Potential of visual/tactile information*

The information potential of visual/tactile symbol systems must be studied further, especially in relation to critical situations. Personal information aids for the visually impaired featuring symbols both printed and raised should be studied to determine criteria for the design of personal information aids for the visually impaired. The feasibility of producing maps of bus routes, neighborhoods and cities must be determined to make such aids accessible to the largest number of visually impaired individuals. The installation of raised environmental cues could be considered, with or without reference to maps.



### *Interdisciplinary research*

Input in the development of improved information aids for the visually impaired must come from potential users in combination with interdisciplinary teams of designers and researchers.



# *Application*

*Designing a map for the visually impaired*



## **Design criteria**

A visual/tactile map for the visually impaired was designed according to the following criteria to show how the proposed symbol set might be applied. It is intended to demonstrate how visual and tactile information might be combined in a simple, specific aid. As the actual production of maps for the visually impaired is outside of the scope of this project, the map is presented here in a mock-up stage.



### *Specific purpose*

One of the needs identified by blind and partially sighted individuals is access to information about the layout of bus transfer points. The transit zone at the University of Alberta was chosen as an example of such a situation made more complex by traffic moving freely throughout. In this situation, it is confusing that University to Downtown buses do not leave from the same side of the street or proceed in the same direction. This is not a typical transit center where bus locations are constant, so only a legend of the Downtown buses can be included.

### *User profile*

This map was designed for use by haptically capable, motivated, independent travellers with some remaining vision who are non-Braille readers and have knowledge of the configurations of the conventional printed alphabet. Tactile symbols were employed to enhance the visual information available to them.



## *Content*

Information to be contained in the map was determined by surveying the region to be mapped on foot. Enough information had to be included on the map to provide essential information without creating conflicting signals in communication. The following landmarks and hazards were considered necessary to this map: **bus stops, bus shelters, specific bus number information, curb breaks, road, crosswalks and the location of relevant adjacent buildings**. A reference system of legend and labels was developed. A reference to direction was included.

## *Symbol selection*

The selection of symbols to be used in the map was based on discriminability performance as measured by this study and on assumed compatibility with environmental features. The best performing symbols in a group were used to represent the most critical features. Labels in large types were included.



## *Production*

The prototypical map was produced through the photomechanical transfer process into acetate, hand-embossed and painted from behind. An optimum production method which combines high symbol discriminability, flexibility of production and use and cost effectiveness does not yet exist for these types of maps. With intensive testing and experimentation, one could be produced commercially through embossment, vacuum forming or thermoforming in combination with a printing process suitable to paper or plastics. Added texture processes are more convenient, but do not provide for the best discriminability. It would be worthwhile to study the effectiveness of a newly developed material called capsule paper that allows a photocopied image to expand when heated. Again, however, this process produces distinct results only in the simplest layouts and only with specific symbols. Both visual and tactile information would have to be developed for use in these separate processes.



### *Availability*

Due to the expense of producing individual maps for specific situations, it is worth considering the development of a complete transit system map from which segments could be produced as needed.

### *Training*

The intended use of this map is to facilitate maneuvering in this specific environment for a specific purpose. For this reason, it is likely that this map would be used at home to learn or memorize the layout prior to travel. This map would require some training from specialists or helpers for optimum efficiency.

### *Evaluation*

The effectiveness of this sample map should be evaluated before it could be produced commercially. Ease of use in terms of size, information content and symbol discrimination must be determined by interviewing potential users and testing in an actual map reading situation.



### *Environmental cues*

A map of any sort would be most useful if visual and tactile cues would relate the environment to the map. In this way, travelers could check their progress against such things as large embossed signs or changes in texture on their travelling surface.



## **Conclusion**

This exhibition has described the design of a proposed system of tactile symbols intended for use in the design of maps for the visually impaired. Although these tactile symbols were developed for use in the design of maps, they can be applied to the design of other informational and educational aids for the visually impaired. Further study and testing in the area of information aids is recommended in an effort to increase the visually impaired person's access to critical information. This should be done by interdisciplinary teams of potential users, psychologists, cartographers, teachers, orientation and mobility specialists, industrial designers and visual communication designers.



Special thanks to University Archives  
& Collections for providing the panel  
frames for the exhibition, and to Lydia  
Bardak, CNIB and University Map  
Collections for providing tactile maps.



## Captions

An added-texture educational map, produced on paper by adding flocking (fibres), glass beads and thermopowder to a wet printed surface and heating at Simon Fraser University and included here courtesy of the Canadian National Institute for the Blind (CNIB).

An added texture educational map produced on acetate at Simon Fraser University and included here courtesy of the CNIB.

An added texture map produced on paper at Simon Fraser University and included here courtesy of the CNIB.

A Swedish tactile map produced in styrene by a thermoforming process in which plastic is heated and molded.

A map produced on capsule paper, which allows a photocopied image to expand when heated.

An urban map commercially printed and thermoformed for blind and sighted users, produced in Washington, D.C. and included here courtesy of the University of Alberta Map Collection.

The same map that appeared on panel number 14, adapted for visually impaired users and included here courtesy of the University of Alberta Map Collection.

A map of a college campus produced in the added texture method using glass beads and flocking on a printed surface, included here courtesy of the CNIB.

A route map embossed in Braille (a type of plastic), included here courtesy of the American Thermoform Company.

## Taxonomy chart

\*sequence is repeated as necessary for symbols with multiple features



Proposed symbol set

Vision barrier

Testing set-up

Symbol pair identification numbers

Proposed symbols discriminable in 95% of total occurrences

Proposed symbols that were not confused with themselves or other symbols in more than 10% of total occurrences

An example of symbols tested for use in maps for the visually impaired, including numerous commercially printed patterns

Mock-up of transit zone map which incorporates highly performing tactile symbols with large type labels. It demonstrates how buildings may be marked with one example.

Materials used in producing the proposed symbol set

Loss of central visual field

Atlas for the blind, courtesy of University of Alberta Map Collection

Legend to the map on Panel 15



*A written report of this project including references will be available from Special Collections.*

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